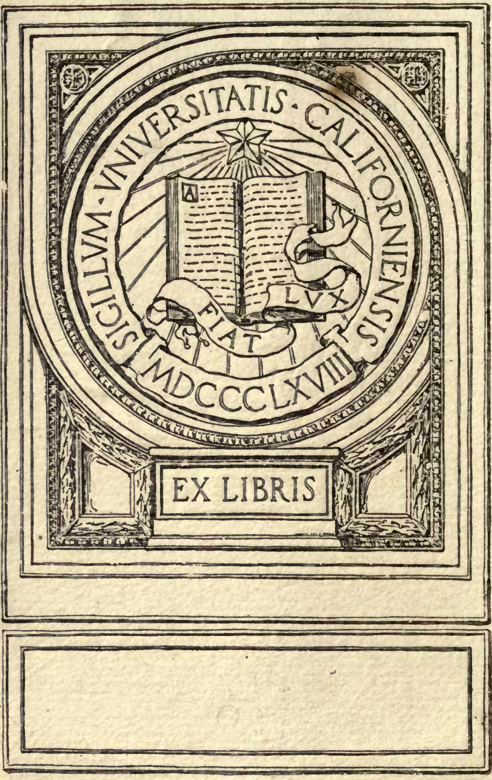
NOTES ON HYDRAULICS

IRA J. OWEN


SIGILLVM · VNIVERSITATIS · CALIFORNIENSIS
FIAT LVX
MDCCCLXVIII
EX LIBRIS

BUYERS' GUIDE

PROTECTIVE CONSTRUCTION AND EQUIPMENT

For Index to Announcements by Corporations, Firms, Individuals, named below, see List of Advertisers, on next Page

NEW YORK CITY

AIR COMPRESSORS
- Deming Co. (Ralph B. Carter Co., 50 Church St.)
- International Sprinkler Co.
- Rockwood Sprinkler Co.
- H. G. Vogel Co.

ELECTRICAL APPARATUS
- H. G. Vogel Co.

FIRE ALARM SYSTEMS, AUXILIARY
- International Sprinkler Co.

FIRE DEPARTMENT SUPPLIES
- H. G. Vogel Co.

FIRE PAILS
- H. G. Vogel Co.

FITTINGS
- General Fire Extinguisher Co.

GAGES, PRESSURE
- H. G. Vogel Co.

GAGES, WATER
- H. G. Vogel Co.

GAS ENGINE POWER
- Challenge Co. (Stothoff Bros., 16 Murray St.)

GOVERNORS FOR PUMPS
- H. G. Vogel Co.

HOSE
- International Sprinkler Co.
- H. G. Vogel Co.

HOSE RACKS AND REELS
- International Sprinkler Co.
- H. G. Vogel Co.

HOSE, UNLINED LINEN
- International Sprinkler Co.
- H. G. Vogel Co.

HYDRANTS
- General Fire Extinguisher Co.
- International Sprinkler Co.
- H. G. Vogel Co.

METERS, WATER
- H. G. Vogel Co.

LIST OF ADVERTISERS.

OIL PUMPS, HAND
Deming Co. (Ralph B. Carter Co., 50 Church St.)
H. G. Vogel Co.

PIPES
General Fire Extinguisher Co.

PIPE HANGERS
H. G. Vogel Co.

PLAY PIPES
H. G. Vogel Co.

PLAY PIPES, MONITOR NOZZLES
H. G. Vogel Co.

PUMPS, CENTRIFUGAL
H. G. Vogel Co.

PUMPS, ELECTRIC
Deming Co. (Ralph B. Carter Co., 50 Church St.)
H. G. Vogel Co.

PUMPS, ROTARY
Deming Co. (Ralph B. Carter Co., 50 Church St.)
H. G Vogel Co.

PUMPS, STEAM
H. G. Vogel Co.

PUMPS, POWER
Deming Co. (Ralph B. Carter Co., 50 Church St.)
H. G. Vogel Co.

SPRINKLERS, AUTOMATIC
General Fire Extinguisher Co.
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

STANDPIPES
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

TANKS, GRAVITY
Challenge Co. (Stothoff Bros., 16 Murray St.)
Rockwood Sprinkler Co.
H. G. Vogel Co.

TANK HEATERS
Rockwood Sprinkler Co.
H. G. Vogel Co.

TANKS, PRESSURE
Rockwood Sprinkler Co.
H. G. Vogel Co.

TANK TELL-TALES
Challenge Co. (Stothoff Bros., 16 Murray St.)
H. G. Vogel Co.

TANK TOWERS, STEEL
Challenge Co. (Stothoff Bros., 16 Murray St.)

VALVES
Challenge Co. (Stothoff Bros., 16 Murray St.)
International Sprinkler Co.
H. G. Vogel Co.

VALVES, ALARM
General Fire Extinguisher Co.
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

VALVES, CHECK
Deming Co. (Ralph B. Carter Co., 50 Church St.)
General Fire Extinguisher Co.
International Sprinkler Co.
H. G. Vogel Co.

VALVES, DRY
General Fire Extinguisher Co.
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

VALVES, FLOAT
Challenge Co. (Stothoff Bros., 16 Murray St.)
Deming Co. (Ralph B. Carter Co., 50 Church St.)
H. G. Vogel Co.

VALVES, FOOT
Rockwood Sprinkler Co.
H. G. Vogel Co.

VALVES, INDICATOR GATE
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

VALVES, POST INDICATOR GATE
General Fire Extinguisher Co.
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

CHICAGO

AIR COMPRESSORS
Beach-Russ Co.
Deming Co. (Henion & Hubbell, 61 N. Jefferson St.)
International Sprinkler Co.
Niagara Fire Extinguisher Co.
Rockwood Sprinkler Co.
Scully Steel & Iron Co.
H. G. Vogel Co.

BARS, IRON & STEEL
Scully Steel & Iron Co.

BEAM STEEL, "I."
Scully Steel & Iron Co.

BLOWERS, POSITIVE PRESSURE
Beach-Russ Co.

BOILERS
National Boiler Works.

BOILER WORKERS' SUPPLIES
Scully Steel & Iron Co.

BOLTS, ALL KINDS
Scully Steel & Iron Co.

BREECHINGS
National Boiler Works.

CANS. OILY WASTE
F. Cortez Wilson & Co.

CORRUGATED IRON
Scully Steel & Iron Co.

ELECTRICAL APPARATUS
H. G. Vogel Co.

ENGINE ROOM SUPPLIES, SHEET METAL
F. Cortez Wilson & Co.

FIRE ALARM SYSTEMS, AUXILIARY
International Sprinkler Co.

FIRE DEPARTMENT SUPPLIES
H. G. Vogel Co.

FIRE PAILS
H. G. Vogel Co.

FITTINGS
General Fire Extinguisher Co.

FLOOR PLATES, WROUGHT STEEL
Scully Steel & Iron Co.

FLUE CLEANERS
Scully Steel & Iron Co.

GAGES, PRESSURE
General Fire Extinguisher Co.
H. G. Vogel Co.

GAGES, WATER
H. G. Vogel Co.

GALVANIZED SHEET STEEL
Scully Steel & Iron Co.

GAS ENGINE TANKS
F. Cortez Wilson & Co.

GAS TANKS
Wm. Graver Tank Works, (East Chicago, Ind.)

GOVERNORS FOR PUMPS
H. G. Vogel Co.

GRAVEL BASINS
National Boiler Works.

HEATERS, EXHAUST STEAM
F. Cortez Wilson & Co.

HOSE
International Sprinkler Co.
H. G. Vogel Co.

HOSE, METAL
Scully Steel & Iron Co.

HOSE RACKS AND REELS
International Sprinkler Co.
H. G. Vogel Co.

HOSE, UNLINED LINEN
International Sprinkler Co.
H. G. Vogel Co.

HYDRANTS
General Fire Extinguisher Co.
International Sprinkler Co.
H. G. Vogel Co.

IRON AND STEEL
Scully Steel & Iron Co.

MACHINERY, BOILER MAKERS AND IRON WORKERS
Scully Steel & Iron Co.

MEASURES, ACCURATE LIQUID
F. Cortez Wilson & Co.

METERS, WATER
H. G. Vogel Co.

NUTS
Scully Steel & Iron Co.

OIL PUMPS, HAND
Deming Co. (Henion & Hubbell, 61 N. Jefferson St.)
H. G. Vogel Co.

OIL PUMPS, POWER
Beach-Russ Co.

OIL PUMPS, SHEET METAL
F. Cortez Wilson & Co.

PENSTOCKS
Wm. Graver Tank Works, (East Chicago, Ind.)

PIPES
General Fire Extinguisher Co.

PIPE, RIVETED
Wm. Graver Tank Works, (East Chicago, Ind.)

PIPE HANGERS
Niagara Fire Extinguisher Co.
H. G. Vogel Co.

PLATES, FLANGE AND TANK STEEL
Scully Steel & Iron Co.

PLATE WORK
Wm. Graver Tank Works, (East Chicago, Ind.)

PLAY PIPES
H. G. Vogel Co.

PLAY PIPES, MONITOR NOZZLES
H. G. Vogel Co.

PUMPS, CENTRIFUGAL
Beach-Russ Co.
H. G. Vogel Co.

PUMPS, ELECTRIC
Beach-Russ Co.
Deming Co. (Henion & Hubbell, 61 N. Jefferson St.)
H. G. Vogel Co.

PUMPS, POWER
Beach-Russ Co.
Deming Co. (Henion & Hubbell, 61 N. Jefferson St.)
H. G. Vogel Co.

PUMPS, ROTARY
Beach-Russ Co.
Deming Co. (Henion & Hubbell, 61 N. Jefferson St.)
H. G. Vogel Co.

PUMPS, SHEET METAL
F. Cortez Wilson & Co.

PUMPS, STEAM
H. G. Vogel Co.

PUMPS, VACUUM
Beach-Russ Co.

RIVETS, BOILER, STRUCTURAL STEEL, SHEET AND TANK
Scully Steel & Iron Co.

ROOFING
Scully Steel & Iron Co.

SHAFTING
Scully Steel & Iron Co.

SHEETS, STEEL, GALVANIZED
Scully Steel & Iron Co.

SMOKE STACKS
National Boiler Works.

SPRINKLERS, AUTOMATIC
General Fire Extinguisher Co.
International Sprinkler Co.
Niagara Fire Extinguisher Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

STANDPIPES
International Sprinkler Co.
Wm. Graver Tank Works, (East Chicago, Ind.)
Rockwood Sprinkler Co.
H. G. Vogel Co.

STEEL, PLATES AND SHEETS
Scully Steel & Iron Co.

TANK CARS
Wm. Graver Tank Works, (East Chicago, Ind.)

TANKS, GAS
Wm. Graver Tank Works, (East Chicago, Ind.)

TANKS, GRAVITY
Wm. Graver Tank Works, (East Chicago, Ind.)
Rockwood Sprinkler Co.
H. G. Vogel Co.

TANK HEATERS
Niagara Fire Extinguisher Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

TANKS, OIL & GASOLINE
F. Cortez Wilson & Co.

TANKS, PRESSURE
Wm. Graver Tank Works, (East Chicago, Ind.)
National Boiler Works.
Rockwood Sprinkler Co.
H. G. Vogel Co.

TANKS, STEEL
Wm. Graver Tank Works, (East Chicago, Ind.)

TANKS, STORAGE
Wm. Graver Tank Works, (East Chicago, Ind.)

TANK-TELL-TALES
H. G. Vogel Co.
TOOLS
Scully Steel & Iron Co.
TOOL STEEL
Scully Steel & Iron Co.
TUBES, IRON, SEAMLESS STEEL
Scully Steel & Iron Co.
VALVES
International Sprinkler Co.
Niagara Fire Extinguisher Co.
H. G. Vogel Co.
VALVES, ALARM
General Fire Extinguisher Co.
International Sprinkler Co.
Niagara Fire Extinguisher Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.
VALVES, BLOW OFF
Scully Steel & Iron Co.
VALVES, CHECK
Deming Co. (Henion & Hubbell, 61 N. Jefferson St.)
General Fire Extinguisher Co.
International Sprinkler Co.
Niagara Fire Extinguisher Co.
H. G. Vogel Co.
VALVES, DRY
General Fire Extinguisher Co.
International Sprinkler Co.
Niagara Fire Extinguisher Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.
VALVES, FLOAT
Deming Co. (Henion & Hubbell, 61 N. Jefferson St.)
H. G. Vogel Co.
VALVES, FOOT
Rockwood Sprinkler Co.
H. G. Vogel Co.
VALVES, INDICATOR GATE
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.
VALVES. POST INDICATOR GATE
General Fire Extinguisher Co.
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.
WASTE CANS
F. Cortez Wilson & Co.
WATER COOLERS
F. Cortez Wilson & Co.
WATER HEATERS
F. Cortez Wilson & Co.
"Z" BARS
Scully Steel & Iron Co.

PHILADELPHIA

AIR COMPRESSORS
Deming Co. (W. P. Dallett, 49 N. Seventh St.)
International Sprinkler Co.
H. G. Vogel Co.

CONTROLLERS (FILTERS)
Simplex Valve & Meter Co.

ELECTRICAL APPARATUS
H. G. Vogel Co.

FIRE ALARM SYSTEMS, AUXILIARY
International Sprinkler Co.

FIRE DEPARTMENT SUPPLIES
H. G. Vogel Co.

FIRE PAILS
H. G. Vogel Co.

FITTINGS
General Fire Extinguisher Co.

GAGES, PRESSURE
H. G. Vogel Co.

GAGES, WATER
H. G. Vogel Co.

GOVERNORS FOR PUMPS
H. G. Vogel Co.

HOSE
International Sprinkler Co.
H. G. Vogel Co.

HOSE RACKS AND REELS
International Sprinkler Co.
H. G. Vogel Co.

HOSE, UNLINED LINEN
International Sprinkler Co.
H. G. Vogel Co.

HYDRANTS
General Fire Extinguisher Co.
International Sprinkler Co.
H. G. Vogel Co.

MANOMETERS
Simplex Valve & Meter Co.

METERS (RECORDING)
Simplex Valve & Meter Co.

METERS, WATER
H. G. Vogel Co.

OIL PUMPS, HAND
Deming Co. (W. P. Dallett, 49 N. Seventh St.)
H. G. Vogel Co.

PIEZOMETERS
Simplex Valve & Meter Co.

PIPES
General Fire Extinguisher Co.

PIPE HANGERS
H. G. Vogel Co.

PLAY PIPES
H. G. Vogel Co.

PLAY PIPES, MONITOR NOZZLES
H. G. Vogel Co.

PUMPS, CENTRIFUGAL
H. G. Vogel Co.

PUMPS, ELECTRIC
Deming Co. (W. P. Dallett, 49 N. Seventh St.)
H. G. Vogel Co.

PUMPS, POWER
Deming Co. (W. P. Dallett, 49 N. Seventh St.)
H. G. Vogel Co.

PUMPS, ROTARY
Deming Co. (W. P. Dallett, 49 N. Seventh St.)
H. G. Vogel Co.

PUMPS, STEAM
H. G. Vogel Co.

SPRINKLERS, AUTOMATIC
General Fire Extinguisher Co.
International Sprinkler Co.
H. G. Vogel Co.

STANDPIPES
International Sprinkler Co.
H. G. Vogel Co.

TANKS, GRAVITY
H. G. Vogel Co.

TANK HEATERS
H. G. Vogel Co.

TANKS, PRESSURE
H. G. Vogel Co.

TANK TELL-TALES
H. G. Vogel Co.

VALVES
International Sprinkler Co.
H. G. Vogel Co.

VALVES (AIR) AUTOMATIC
Simplex Valve & Meter Co.

VALVES, ALARM
General Fire Extinguisher Co.
International Sprinkler Co.
H. G. Vogel Co.

VALVES, ALTITUDE
Simplex Valve & Meter Co.

VALVES, CHECK
Deming Co. (W. P. Dallett, 49 N. Seventh St.)
General Fire Extinguisher Co.
International Sprinkler Co.
H. G. Vogel Co.

VALVES, CONTROLLING (STANDPIPE)
Simplex Valve & Meter Co.

VALVES, DRY
General Fire Extinguisher Co.
International Sprinkler Co.
H. G. Vogel Co.

VALVES, FLOAT
Deming Co. (W. P. Dallett, 49 N. Seventh St.)
H. G. Vogel Co.

VALVES, FOOT
H. G. Vogel Co.

VALVES, INDICATOR GATE
International Sprinkler Co.
H. G. Vogel Co.

VALVES, POST INDICATOR GATE
General Fire Extinguisher Co.
International Sprinkler Co.
H. G. Vogel Co.

VENTURI TUBES
Simplex Valve & Meter Co.

ST. LOUIS

AIR COMPRESSORS
Deming Co. (Chas. S. Lewis & Co.)
International Sprinkler Co.
Niagara Fire Extinguisher Co.

FIRE ALARM SYSTEMS, AUXILIARY
International Sprinkler Co.

FITTINGS
General Fire Extinguisher Co.

HOSE
International Sprinkler Co.

HOSE RACKS AND REELS
International Sprinkler Co.

HOSE, UNLINED LINEN
International Sprinkler Co.

HYDRANTS
General Fire Extinguisher Co.
International Sprinkler Co.

OIL PUMPS, HAND
Deming Co. (Chas. S. Lewis & Co.)

PIPES
General Fire Extinguisher Co.

PIPE HANGERS
Niagara Fire Extinguisher Co.

PUMPS, ELECTRIC
Deming Co. (Chas. S. Lewis & Co.)

PUMPS, POWER
Deming Co. (Chas. S. Lewis & Co.)

PUMPS, ROTARY
Deming Co. (Chas. S. Lewis & Co.)

SPRINKLERS, AUTOMATIC
General Fire Extinguisher Co.
International Sprinkler Co.
Niagara Fire Extinguisher Co.

STANDPIPES
International Sprinkler Co.

TANK HEATERS
Niagara Fire Extinguisher Co.

VALVES
International Sprinkler Co.
Niagara Fire Extinguisher Co.

VALVES, ALARM
General Fire Extinguisher Co.
International Sprinkler Co.
Niagara Fire Extinguisher Co.

VALVES, CHECK
Deming Co. (Chas. S. Lewis & Co.)
General Fire Extinguisher Co.
International Sprinkler Co.
Niagara Fire Extinguisher Co.

VALVES, DRY
General Fire Extinguisher Co.
International Sprinkler Co.
Niagara Fire Extinguisher Co.

VALVES, FLOAT
Deming Co. (Chas. S. Lewis & Co.)

VALVES, INDICATOR GATE
International Sprinkler Co.

VALVES, POST INDICATOR GATE
General Fire Extinguisher Co.
International Sprinkler Co.

BOSTON

AIR COMPRESSORS
Deming Co. (Chas. J. Jager Co., 281 Franklin St.)
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

ELECTRICAL APPARATUS
H. G. Vogel Co.

FIRE ALARM SYSTEMS, AUXILIARY
International Sprinkler Co.

FIRE DEPARTMENT SUPPLIES
H. G. Vogel Co.

FIRE ESCAPES
New England Tank & Tower Co.

FIRE PAILS
H. G. Vogel Co.

FITTINGS
General Fire Extinguisher Co.

GAGES, MERCURY
New England Tank & Tower Co.

GAGES, PRESSURE
H. G. Vogel Co.

GAGES, WATER
H. G. Vogel Co.

GOVERNORS FOR PUMPS
H. G. Vogel Co.

(Continued on Page 17)

NOTES ON HYDRAULICS

A Pocket Book of Useful Data for
Engineers, Architects,
Factory Managers,
Fire Insurance Inspectors
and Students

By

IRA J. OWEN, M. E.
Consulting Engineer
Junior American Society Mechanical Engineers

NEW YORK:
THE INSURANCE PRESS

GLOBE
PRINTING
COMPANY
7 DUTCH STREET
NEW YORK CITY

PREFACE

THE OBJECT of this book, as conceived by the author, is to provide simplified rules and forms for the convenience of Engineers, Architects and the Insurance Fraternity. It is intended to be an aid in solving hydraulic problems that commonly occur in Fire Insurance Engineering.

Many of the subjects herein contained may have been more extensively treated than would seem necessary and consistent for a book of this character. This, however, has been done for the benefit of those who have not had the advantage of a theoretical training and to whom a book of this character would be of little use were they not supplied with a few elementary principles by which means they may learn to use and understand these Formulæ.

Most of the Rules and Formulæ herein given are taken from authorities and standard works on the subject, although perhaps appearing in new form for the purpose of making them more simple.

Amendments to certain requirements and specifications for standard appliances have been included.

There are those into whose hands this work will fall who are entirely competent to criticise it, both as to usefulness and accuracy. From such critics the author invites criticisms and suggestions and contributions of fresh material that may be useful for future editions.

I. J. O.

INDEX

Theory of the Flow of Water.

For reference, see Weisbach's Mechanics, Vol. 1; Church's Mechanics, Encyclopædia Britannica.

THE following is a concise statement of the principles involved:

In the flow of water, the particles are urged onward by gravity, or an equivalent force, and move with the same velocity as bodies falling through a height, equal to the head of water exerting the pressure.

Velocity.

Is the rapidity with which a particle moves, *i e.,* its rate of motion, or rate of change of position.

Uniform Velocity.

When the change of position in the second, third, or any subsequent unit of time is the same as described in the first unit, the velocity is said to be uniform.

Note.

Velocities are generally expressed in ft. per sec. in all hydraulic formulas.

Time.

The unit of time used in all hydraulic formulas is the Second.

Unit of Work or Energy.

Is the foot-pound, *i. e.,* One pound lifted through a vertical distance of one foot.

One H. P. = 33,000 ft. — lbs. per min. or 33,000 lbs. lifted a distance of one ft. in one minute.

Unit of Weight.

Is the avoirdupois pound, which is also the unit for measuring pressures. The intensity of pressure will be measured in pounds per square foot or in pounds per square

inch as may be most convenient, and sometimes in atmospheres.

Gages for recording the pressures of water are usually graduated so as to read in pounds per square inch.

Gravity.

The symbol (g) is used to denote the acceleration of gravity; that is, the increase in velocity per second for a body falling freely in a vacuum at the surface of the earth. At the end of (t) seconds from the beginning of the fall, the velocity of the body is

$$V = gt \quad \text{or} \quad t = \frac{V}{g} \qquad (1)$$

The space (h) passed over in this time is the product of the mean velocity and the time (t) in seconds:—

$$h = \tfrac{1}{2}Vt \quad \text{or} \quad t = \frac{2h}{V} \qquad (2)$$

Eliminating (t) by substituting Eq. 1 in 2 we have

$$\frac{V}{g} = \frac{2h}{V} \qquad \therefore\ V = \sqrt{2gh}$$

which is the fundamental formulæ in hydraulics.

32.2 feet per sec. is an approximate value for (g) which is the value used in all computations in this book. The above equation may be stated as follows:

THE VELOCITY IS EQUAL TO THE SQUARE ROOT OF TWO TIMES THE VALUE OF GRAVITY MULTIPLIED BY THE HEAD OR PRESSURE WHICH PRODUCES THAT VELOCITY.

ATMOSPHERIC PRESSURE.

Atmospheric pressure is measured by the readings of the Barometer.

The pressure of the air on the surface of the liquid causes it to rise in the tube, until it attains a height which exactly balances the pressure of the air, *i e.*, the weight of the barometric column, is equal to the weight of a column of air of the same cross-section as that of the tube.

The liquid generally employed is mercury which weighs 0.49 pounds per cubic inch at common temperatures.

THEREFORE to obtain the value of the atmospheric pressure, multiply the barometric reading in inches, by 0.49.

Example:

The average barometric reading near the sea level is 30 inches, then

$30 \times 0.49 = 14.7$ pounds per sq. inch or the value of one atmosphere.

ABSOLUTE PRESSURE.

The pressure of the atmosphere as stated above is about 14.7 lbs. per square inch. Gages are usually indexed so that the zero reading is at atmospheric pressure. The absolute pressure then is the sum of the atmospheric pressure and the indicated or gage pressure. Thus if the pressure gage reads 10 pounds the absolute pressure would be $10 + 14.7 = 24.7$ lbs. per square inch absolute.

BERNOULLI'S THEOREM FOR STEADY FLOW WITHOUT FRICTION.

If a pipe is comparatively short without sudden bends, elbows or abrupt changes of cross-section, the effect of friction of the liquid particles against the sides of the pipe and against each other (as when eddies are produced, disturbing the parallelism of flow), is small and can be neglected.

Denoting by potential head the vertical head of any section of pipe above a convenient datum level, we may state Bernoulli's Theorem as follows:

IN THE STEADY FLOW WITHOUT FRICTION THE SUM OF THE VELOCITY HEAD, PRESSURE HEAD AND POTENTIAL HEAD AT ANY SECTION OF PIPE, IS A CONSTANT QUANTITY BEING EQUAL TO THE SUM OF THE CORRESPONDING HEADS AT ANY OTHER SECTION.

It must be clearly understood that Bernoulli's Theorem does not hold unless the flow of water is steady; that is, unless each lamina in coming into the position just vacated by the one next ahead of (equal mass), comes also into the exact conditions of velocity and pressure in which the other was when in that position.

Bernoulli's Theorem may also be stated by the following equation:

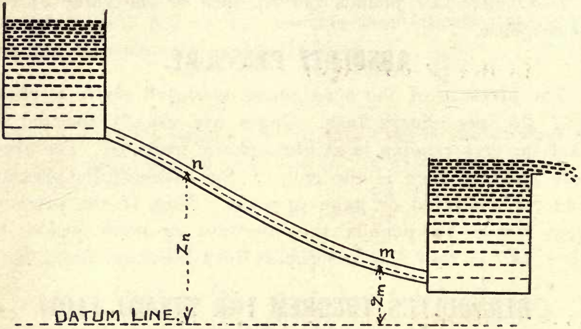


FIG. 1

$$\frac{V_m^2}{2g} + \frac{p_m}{y} + z_m = \frac{V_n^2}{2g} + \frac{p_n}{y} + z_n$$

Where $\frac{V_m^2}{2g}$ = Velocity head at Section m of pipe.

$\frac{p_m}{y}$ = Pressure head at Section m of pipe.

z_m = Potential head at Section m of pipe.

$\frac{V_n^2}{2g}$ = Velocity head at Section n of pipe.

$\frac{p_n}{y}$ = Pressure head at Section n of pipe.

z_n = Potential head at Section n of pipe.

See Fig. No. 1.

BERNOULLI'S THEOREM FOR STEADY FLOW WITH FRICTION.

If a pipe is of considerable length or has a number of sudden bends or elbows or abrupt changes of cross-section, the Bernoulli's Theorem for steady flow without friction, will not hold, as frictional losses are produced and in determining the pressure and quantity of water flowing through a pipe, these losses must be taken into consideration.

Taking into account no resistances or friction except the "skin friction" or "fluid friction" of the liquid on the sides of the pipe (resistances due to internal friction or of eddying occasioned by sudden enlargements of cross-section of pipe by elbows, sharp curves, gate valves, etc., will be mentioned later).

Bernoulli's Theorem for steady flow of a liquid in a pipe of slightly varying sectional area and internal perimeter w, may be stated as follows:

THE SUM OF THE VELOCITY HEAD, PRESSURE HEAD AND POTENTIAL HEAD AT ANY SECTION OF THE PIPE IS EQUAL TO THE CORRESPONDING HEADS AT ANY OTHER SECTION MINUS THE FRICTION HEAD OR RESISTANCE HEAD, DUE TO SKIN FRICTION BETWEEN THE SECTIONS.

PRESSURE HEAD, VELOCITY HEAD AND STATIC HEAD.

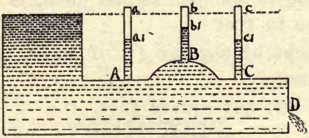


FIG. 2

When a vessel is filled with water at rest, the pressure at any point depends only on the head of water above that point. But when the water is in motion it is a fact of

observation that the pressure becomes less than that due to head. The actual pressure in any event may be measured by the height of a column of water.

Thus, if the water be at rest in the case shown in the Fig. 2 and small tubes (open Piezometers) be installed at A, B, C, the water will rise in each tube to the same height as that of the water level in the reservoir, and the pressures at A, B and C will be those due to heads Aa, Bb and Cc. But if an orifice be open as seen near D, the water levels in the tubes sink to the points a_1, b_1 and c_1 — *i. e.*, the pressures at A, B, C are reduced to those due to the heads Aa_1, Bb_1, and Cc_1.

Aa_1 is the PRESSURE HEAD P

aa_1 is the VELOCITY HEAD $\frac{v^2}{2g}$

Aa is the HYDROSTATIC or STATIC HEAD h

The theoretical Velocity of flow is $V = \sqrt{2gh}$ (1)

The theoretical height the jet will rise is then $h = \frac{v^2}{2g}$ (2)

Equation 1 states the velocity due to a given head. Equation 2 the head which would generate a given velocity.

The term VELOCITY HEAD is designated by $\frac{v^2}{2g}$ meaning thereby that its value is the head which can produce the velocity V.

If p is taken in lbs. per square inch, or gage pressure,
and h is taken in feet
and w = weight of a cubic ft. of water = 62.5# approximately.

Then p = hw lbs. per square foot,

or $p = \frac{hw}{144}$ lbs. per square inch.

p = 0.434 h Gage pressure in terms of hydrostatic head.

h = 2.304 p Hydrostatic head in terms of gage pressure.

The STATIC HEAD or EFFECTIVE HEAD, as can readily be seen, equals the pressure head plus the velocity head.

Let—

h = static head

h_1 = pressure head—head due to actual pressure

$\frac{v^2}{2g}$ = head due to actual velocity.

Then— $$h = h_1 + \frac{v^2}{2g}$$

or in the form of a theorem:—

THE PRESSURE HEAD PLUS THE VELOCITY HEAD IS EQUAL TO THE TOTAL HYDROSTATIC HEAD.

Proof—

Let W equal the weight of water which passes the section per second—

Then— $W \frac{v^2}{2g}$ is the energy which it possesses.

The total theoretical energy of this water is Wh, and if there be no losses of energy, the remaining energy is

$W h_1 = W \times (h - \frac{v^2}{2g})$ which represents the potential energy still existing in the form of pressure.

THEREFORE $h - \frac{v^2}{2g} = h_1$ or $h = h_1 + \frac{v}{2g}$ *Qed.*

COEFFICIENTS.

A coefficient as applied in hydraulics may be defined as a number or multiplier introduced into an expression or equation for the purpose of reducing the theoretical to a true value, or nearly so.

It is found that in the actual discharge of water, except in rare cases, the actual velocity of discharge is less than the theoretical, that the area of the stream discharged is less than the area of the orifice through which it passes, etc., etc.

These losses are corrected by introducing coefficients, and the following are definitions of a number of coefficients commonly used in hydraulic formulæ and also the manner in which they are obtained from experiment:

COEFFICIENT OF CONTRACTION.

Is the number by which the area of the orifice is to be multiplied in order to obtain the area of the section of the jet at a distance from the plane of the orifice of about one-half its diameter. Thus if C_c be the coefficient of contraction, (A) the area of the orifice, and (a) the area of the contracted section of the jet—

then $$C_c\ A = a$$

$$C_c = \frac{a}{A} = \frac{\pi\ d^2}{\pi\ D^2} = \left(\frac{d}{D}\right)^2$$

IT MAY ALSO BE DEFINED (AS CAN BE SEEN BY THE ABOVE EQUATION) AS THE SQUARE OF THE RATIO OF THE DIAMETER OF THE JET TO THAT OF THE ORIFICE.

The mean or average value of C_c the coefficient of contraction, has been given by different authorities as .61 .63 .64.

These values vary for different forms of orifices and for the same orifice under different heads, but little is known regarding the extent of these variations or the laws that govern them.

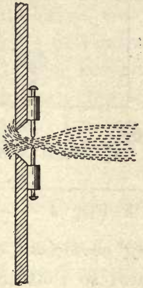


FIG. 3

Probably C_c is slightly smaller for circles than for squares, and smaller for squares than for rectangles. Probably C_c is larger for low heads than for high heads.

The coefficient of contraction is directly determined by measuring the dimensions of the least cross-section of the jet.

This may be accomplished by the use of calipers or by means of fixed screws of fine pitch (see fig. 3) which are very convenient. These are set to touch the jet and then the distance between them can be measured at leisure.

COEFFICIENT OF VELOCITY.

The coefficient of velocity is the number by which the theoretical velocity of flow from the orifice is to be multiplied, in order to give the actual velocity at the least cross-section of the jet:

Thus—if C_v be the coefficient of velocity, V the theoretical velocity due to head on the center of the orifice, and v the actual velocity at the contracted section—

$$v = C_v \times V = C_v \sqrt{2gh}$$

The velocity of flow at the contracted section of the jet cannot be directly measured.

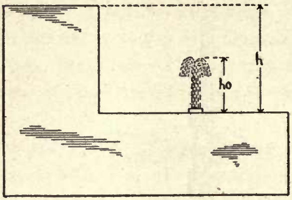


FIG. 4

One method of finding coefficient of velocity (C_v) is to place the orifice horizontal so that the jet will be directed vertically upward as in fig. 4. The height to which it rises is the velocity head—

$$h_o = \frac{v^2}{2g} \qquad (1)$$

in which v is the actual velocity and is equal to $C_v \sqrt{2gh}$. Substituting this in eq. (1) we have

$$h_o = C_v^2\, h \text{ and } C_v = \sqrt{\frac{h_o}{h}}$$

from which C_v may be computed. This method fails to give good results for high velocities, owing to the resistance of the air and the difficulty in measuring the distance h with precision.

A mean or average value for C_v, the coefficient of velocity is .98.

The coefficient of velocity in smooth nozzles is the same as the coefficient of discharge, since the jet issues without contraction.

COEFFICIENT OF DISCHARGE.

The coefficient of discharge is the number by which the theoretical discharge is to be multiplied in order to obtain the actual discharge. Thus if c be the coefficient of discharge, Q the theoretical, and q the actual discharge per second—

then— $q = c \times Q.$

The coefficient of discharge may also be defined as the product of the coefficients of contraction and velocity.

In general c is greater for low heads than for high heads, greater for rectangles than for squares, and greater for squares than for circles. Its value ranges from 0.59 to 0.63 or higher, and as a mean the following value may be stated:

c Coef. of Discharge = 0.61.

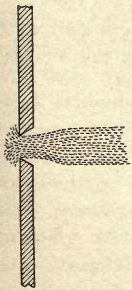
The actual discharge from a standard orifice is, on the average, about 61% of the theoretical discharge.

The coefficient of discharge can be accurately found by allowing the flow from an orifice to discharge into a tank and the volume measured as explained in article on measurement of water. Thus q the actual discharge is known and Q the theoretical discharge having been computed, the coefficient of discharge will be equal to q divided by Q or

$$c = \frac{q}{Q}$$

STANDARD CIRCULAR ORIFICES.

Standard Circular Orifices with sharp edges *i. e.* where the water does not touch the orifice after having passed the inner edge. See fig. 5.



Coef. of Discharge = .61.

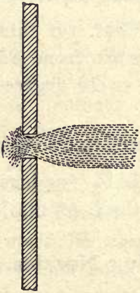


FIG. 5

FIG. 6

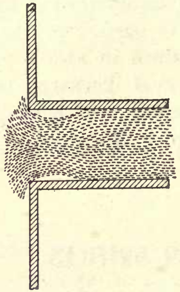
Orifices with Rounded Edges.

When the inner edges of the orifice are rounded. See fig. 6.

Coef. of Discharge varies from .61 to 1.00.

Short Cylindrical Tube.

i.e. where length of tube is 2½ to 3 times the diameter, and inner corner sharp as standard orifice. See fig. 7.



Coef. of discharge = .82.

FIG. 7

Short Conical Converging Tubes.

Coef. for this form will vary with the angle (A) at the Vertex from .85 to .95. Where the angle at the Vertex is 10 to 15 degrees, the coef. of discharge is .94.

Smooth Nozzles.

Like "underwriters play pipe."
Coef. of discharge .976

Ring Nozzles.

Coef. of discharge .74

Mr. J. R. Freeman furnishes the following mean or average values of the coefficient of discharge for smooth cone nozzles of different diameters under pressure heads ranging from 45 to 180 ft.:

Diam. in Inches.	Coef. of Disch.
$\frac{3}{4}$	.983
$\frac{7}{8}$	.982
1	.972
$1\frac{1}{8}$	.976
$1\frac{1}{4}$	.971
$1\frac{3}{8}$	.959

THE MEASUREMENT OF WATER AND INSTRUMENTS USED.

There are many ways by which the determination of a cubic volume of water that passes a given point in a unit of time can be made. A brief discussion of a few of the methods in common use will be taken up in this chapter.

THE TANK.

The simplest of all methods of measuring water is by the use of the tank. At first sight this method seems extremely simple, but in reality if accuracy is required, measuring water by means of a measuring tank requires considerable skill. Two methods may be employed in measuring tank volumes. First, by directly computing the cubical contents, and second, by weighing the volume of water and computing the contents from the temperature of the contained water and from its weight per cubic foot, corresponding to the temperature. In computing the cubical contents (the tank if of wood the wood must be thoroughly water-logged) the water level must be accurately determined and the linear measurements must be correct. It can be readily seen that if the sides are slightly

warped or if the form is irregular, to obtain accurate results would mean a laborious undertaking. It is, therefore, advisable in measuring volumes in this way that a tank of regular form without warps and one which will not absorb water should be used.

It is obvious that the easier method is by weighing the water, taking its temperature and computing the volume from this data.

Kent gives the following as the weight of water per cubic foot at different temperatures from 32 to 100 degrees Fahr.:

Temp. Degs. Fahr.	Lbs. Per Cu. Ft.	Temp. Degs. Fahr.	Lbs. Per Cu. Ft.	Temp. Degs. Fahr.	Lbs. Per Cu. Ft.	Temp. Degs. Fahr.	Lbs. Per Cu. Ft.	Temp. Degs. Fahr.	Lbs. Per Cu. Ft.
32	62.42	46	62.42	60	62.37	74	62.28	88	62.15
33	62.42	47	62.42	61	62.37	75	62.28	89	62.14
34	62.42	48	62.41	62	62.36	76	62.27	90	62.13
35	62.42	49	62.41	63	62.36	77	62.26	91	62.12
36	62.42	50	62.41	64	62.35	78	62.25	92	62.11
37	62.42	51	62.41	65	62.34	79	62.24	93	62.10
38	62.42	52	62.40	66	62.34	80	62.23	94	62.09
39	62.42	53	62.40	67	62.33	81	62.22	95	62.08
40	62.42	54	62.40	68	62.33	82	62.21	96	62.07
41	62.42	55	62.39	69	62.32	83	62.20	97	62.06
42	62.42	56	62.39	70	62.31	84	62.19	98	62.05
43	62.42	57	62.39	71	62.31	85	62.18	99	62.03
44	62.42	58	62.38	72	62.30	86	62.17	100	62.02
45	62.42	59	62.38	73	62.29	87	62.16		

When limiting the length of time during which the stream whose flow is desired to be measured discharges into the tank, a convenient way is to use a movable spout by which the stream of water may be made to discharge into the tank and again to one side of it at given signals. By the use of a stop-watch the length of time may be determined during which the tank receives the discharge to be measured.

PRESSURE GAGES.

One of the most common used pressure gages is Bourdon's, and is illustrated in fig. 8.

It consists of a bent metal tube eliptical in cross-section which is put in connection with the interior of the pipe or tank in which the pressure is to be measured, by means of a pipe which is provided with a stop cock. The effect of the internal pressure on the tube is to tend to transform the eliptical into a circular cross-section. This, however, cannot be done without partially unbending or straightening the tube aa, that is to say, the effect of internal pressure is alternately to straighten the tube and the greater the pressure the more the tube is unbent, and consequently, the more the free end c is moved from its normal position. The free end is connected by means of a link with an index like the hand of a watch either directly or else through the medium of the small rack and pinnon, which multiplies the motion of the index. When the free end of the tube moves under the

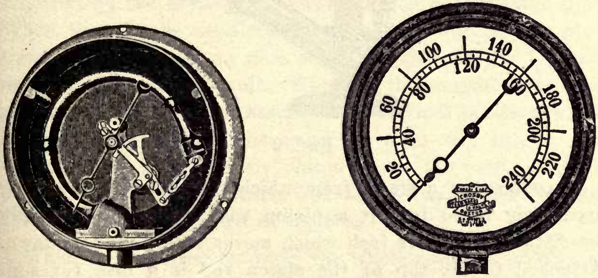


Fig. 8

influence of pressure, the end of the index describes an arc of a circle. By placing a dial behind the index and graduating the former experimentally so that a given position of the needle corresponds with a given pressure in the tube, we obtain an exact pressure gage.

APPARATUS FOR TESTING GAGE.

Mercury columns have long been accepted as the standard for measuring pressures, but are so expensive and difficult to keep in order that a more simple and inexpensive, yet accurate, machine is required. Apparatus of this nature consists of a pump or other means of obtaining pressure and some methods of attaching the gage to be tested and the standard with which it is to be compared.

One of the forms of gage testers now in common use is shown in fig. 9.

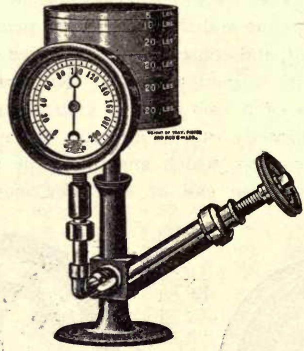


FIG. 9

It consists of a stand from which rises a cylinder having accurately fitted into it a piston with an area of exactly one-fifth of a square inch which moves freely up and down. Attached to the top of the piston rod is a disc for supporting the weights. Each weight is marked with the number of pounds pressure per square inch it will exert on the gage. From the bottom of the cylinder 2 tubes project; one forms a standard for holding the gage to be tested and one is furnished with a coupling to connect it, and with a three-way cock; the other rises at an inclination and forms a reservoir for oil, having within it a screw plunger for forcing the oil inward or outward.

DIRECTIONS FOR USING GAGE TESTER.

Fasten the gage to the arm by means of a coupler or similar arrangement; set the handle of a three-way cock horizontally or in an open position; see that the screw plunger is in as far as it will go, then remove the cap and pour oil into the cylinder until it is full, then gradually withdraw the plunger and continue pouring in oil until it is out nearly to its limit and the bore of the cylinder is nearly full. Now insert the piston which with its disc will exert a pressure on the gage of exactly the weight of the disc and piston. The weights, one at a time, may now be placed on the disc which should be gently rotated to insure perfect freedom of motion to the piston. Each weight added will exert a pressure on the gage equal to the number of pounds marked on it.

If in testing a large gage the piston descends to its full length, screw in the plunger and the piston will be forced upward and more weights may be added as may be required by the limit of pressure marked on the gage dial. When the test is completed remove the weights, one at a time, and as the piston rises withdraw the plunger to make room for the returning oil. When all the weights have been removed, turn the cock handle to a vertical position which will allow the oil in the gage to drain out into a can which should be previously placed under the cock. The oil may be left in the machine, but the piston should be carefully wiped and replaced in the case.

When it is desired to drain the whole machine of oil, set the cock handle so that the port leading to the reservoir for oil will be open.

It is advisable to use nothing but good light mineral oil which should be kept entirely free from grit.

The following is a form that is used quite frequently in calibrating pressure-gages of this type:

CALIBRATING OF PRESSURE-GAGE WITH GAGE TESTER.

Maker and No. of Gage..

Date..........................190

....

Observers,

....

No.	Load in lbs. on Valve	Gage	Error	Remarks

PITOT TUBE.

In measuring pressure exerted by moving water in a pipe, both the velocity head and pressure head have to be taken into consideration. To separate these two factors, an instrument known as the Pitot Tube may be used.

One form of this instrument is shown in the following figure 10:

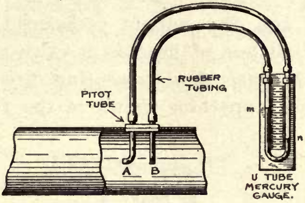


FIG. 10

Tube A is open at the end and connects by rubber tube to one arm of an ordinary U tube mercury gage, the other, tube B, is closed upon the end, but has in its opposite side two small holes and is connected to the other arm of the gage.

Tube A receives the full effect of the current of moving water and thus tends to indicate upon the gauge the total head, including both the velocity and the pressure heads. But the influence of the velocity is practically removed from B, which, therefore, receives only the pressure due to the pressure head. As this tube is connected to the other arm of the gage, the pressure thus indicated is only that due to the velocity head; for both arms being subject to the pressure head these pressures are balanced.

The difference in height of the mercury in the gage would be that due to velocity of current; thus, if the mercury stands at m on one side and at n on the other, the velocity is that due to the height of the column of liquid, equal to the distance that m is above n. Call this distance h, then the velocity $v = c \times \sqrt{2gh}$; c is the coefficient of velocity for the given tube and must be determined by experiment made on a tube in which the velocity of flow is known.

The principal use of this instrument is to determine the velocity of the flowing water.

MERCURY GAGE FOR DETERMINING LOSS OF HEAD OR PRESSURE.

Some time ago the author occasioned to investigate closely the actual loss of head in a valve under high pressure and for the purpose of measuring directly this loss, he devised a simple apparatus shown in the following sketch, fig. 11:

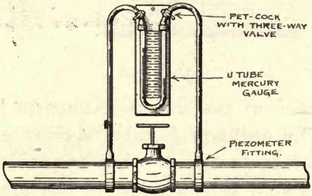


FIG. 11

The difference in hydraulic pressure existing in any two points in a line of water pipe is at once exhibited by the difference in height of two communicating columns of mercury. The apparatus is, therefore, merely a pressure difference gage which has the merit of being both sensitive and accurate and which may also be applied in other similar investigations.

In principle the gage consists of a glass U tube par tially filled with mercury, while the upper ends of these tubes are connected to the water main by means of suitable cocks and piping. On the admission of water into the two tubes the mercury will be depressed in one and raised in the other until equilibrium is established. Whereupon, the difference in the height of the two mercury columns is to be read off on a suitable scale whose divisions correspond to known pressures of water as determined by careful experiments beforehand. In practice, however, it is necessary to exercise the utmost care to expel all the air in the tubes above the mercury, which may be accomplished by judicious manipulation of the pet-cocks.

In using this gage as a pressure difference gage the principal correction to be made is that due to excess water columns on the short leg of the U tube. This correction for any pressure is the distance in inches between the surfaces of the mercury, multiplied by .036, this equals the number of pounds to be subtracted from the reading of the short leg.

VENTURI METER.

Another method of measuring water is by means of the Venturi Meter, so called from Venturi, who first pointed out the relation between the pressures and velocities of flow in converging and diverging tubes.

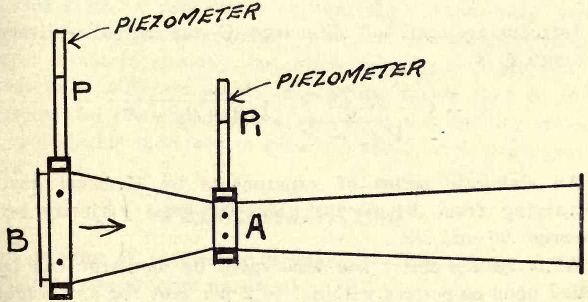


FIG. 12

As shown by the longitudinal section Fig. 12 this meter consists of a converging, followed by a gently diverging, tube; between the two is a short cylindrical piece known as the throat. A and B are air or pressure chambers which are connected with the interior by piezometer holes. Piezometers are connected as shown by which the fluid pressure may be measured.

It is a fundamental principle in hydraulics that the hydraulic pressure of water in motion against the interior of a pipe is equal to the hydrostatic head (pressure of water not in motion) less the head due to velocity. If P be the pressure in terms of the height of a water-column at the inlet B and P_1 be the pressure in terms of the height of a water-column at the throat A, P_1—P equals the difference of heads in the piezometers or the "head on Venturi," as it is called.

a_1 and a_2 equals the sectional areas at A and B respectively.

Then the quantity of flow at A is

$$Q = \frac{a_1 \times a_2}{\sqrt{a_2^2 - a_1^2}} \sqrt{2g\,(P_1 - P)}$$

Introducing coef. of discharge C the actual delivery through A is

$$Q = C \frac{a_1 \times a_2}{\sqrt{a_2^2 - a_1^2}} \sqrt{2g\,(P_1 - P)}$$

An elaborate series of experiments by Herschel gave C varying from .94 to 1.04, but the great majority lay between .96 and .99.

After such a meter has been rated its discharge can be relied upon as correct within 1 to 2 per cent for any single reading.

PIEZOMETERS.

A piezometer is an instrument for measuring the pressure of water which exists in a pipe. The simplest form of this instrument consists of an ordinary tube inserted into a pipe at right angles. The water will rise in the tube to a height equal to the pressure exerted at the point where the piezometer or tube is installed.

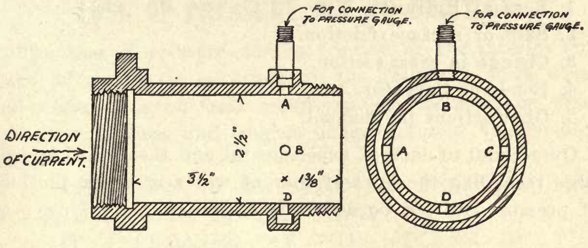


Fig. 13

A,B,C,D, are piezometer orifices. Both screw ends fit Standard Hose Couplings, so piezometer may be introduced at any joint in a line of hose or at the base of Play Pipe, coupling thus forming part of line.

This form of piezometer answers the purpose very well for measuring static pressures (pressure due to head, when water is not in motion), but when water is in motion the pressure at different points in the pipe varies, that is, the pressures at the top, bottom, and sides are not the same. It is desirable therefore to know the mean or average pressure.

PIEZOMETER FITTING.

A number of piezometer fittings have been designed for obtaining the average pressure.

Figure 13 shows the cross-section of a piezometer fitting designed by Mr. J. R. Freeman and used very successfully in his tests on fire streams.

LOSS OF HEAD OR PRESSURE.

The loss of head or pressure or RESISTANCE TO FLOW commonly though INCORRECTLY called FRICTION, between any two points in a pipe line may consist of any one or more of the following:

1. Loss at Entrance.
2. Skin or surface friction.
3. Change in cross-section.
4. Bends or Curvature.
5. Obstructions in Channel.

On account of lack of experimental and theoretical knowledge regarding the laws of flow of water in pipes, the loss of pressure can not be definitely computed.

LOSS OF PRESSURE AT ENTRANCE.

The loss of pressure which occurs in the upper end of a pipe due to contraction and resistance of the inner edges, is called LOSS OF HEAD OR PRESSURE AT ENTRANCE and is the same as the loss of head in a short cylindrical tube under the same velocity of flow. This loss is always less than the velocity head, therefore, where h_E equals the loss of head at entrance we have

$$h_E = K \frac{v^2}{2g}$$

The value for K varies from 0 to .93

For a perfect mouth piece K equals 0

For an inward projecting pipe K equals .93

For a standard end K equals .50

Example:—Compute the loss of head at entrance in a 1 inch pipe 100 feet long discharging 15 gallons per minute:

$$\text{Velocity} = \frac{\text{Discharge in cubic ft. per sec.}}{\text{Area in square feet}} \quad \frac{.033}{.0054} = 6.11 \text{ ft. per sec.}$$

$$h_E = K \frac{(6.11)^2}{2 \times 32.2} = K \frac{37.33}{64.4} = K\ .579$$

Assuming K to equal .5 then

$h_E = .5 \times .579 = .2895$ feet, loss of head due to entrance.

LOSS OF PRESSURE DUE TO FRICTION.

The loss of pressure due to friction of the interior surface of a pipe is governed by the following laws which have been deduced from many experiments made on pipes of different sizes and lengths under different velocities of flow.

1. THE LOSS IN FRICTION IS PROPORTIONAL TO THE LENGTH OF THE PIPE.

2. IT INCREASES AS THE SQUARE OF THE VELOCITY.

3. IT DECREASES AS THE DIAMETER OF THE PIPE INCREASES.

4. IT INCREASES WITH THE ROUGHNESS.

5. IT IS INDEPENDENT OF THE PRESSURE OF THE WATER.

Let

L equal the length of pipe.
d equal the diameter of pipe.
H_F equal the head or pressure lost due to friction.
f equal a coefficient depending on the roughness of the interior surface of the pipe.

Then these laws may be expressed by the following equation:—

$$H_F = f \frac{L}{d} \frac{v^2}{2g}$$

The factor f for new clean pipes ranges from .05 to .01.

For approximate computations the mean or average value for f, .02 may be used.

Example:—Find the loss of head in 100 feet of pipe 2 inches in diameter when discharging 150 gallons of water per minute.

$$H_F = .02 \frac{100}{.17} \frac{225}{64.4} = 40 \text{ feet.}$$

The velocity v is obtained by dividing the discharge in cubic feet per second by the area of the pipe in square

feet; thus the area of a 2-inch pipe is .022 the discharge in cubic feet per second is $150 \div 60 \div 7.48 = .334$.

Then .334 divided by .022 equals 15 the velocity, and v^2 is 225.

LOSS OF HEAD OR PRESSURE DUE TO BENDS.

The loss of pressure caused by easy curves is very slight and need not be taken into consideration. Where there is a sharp bend such as an elbow the loss is small, but where a number of such bends occur the loss may amount to considerable. This loss is a percentage of the velocity head and may be expressed by the equation $H_B = n \frac{V^2}{2g}$ Where H_B is the loss due to the bend, and n the coefficient.

Weisbach gives the following values for n which were derived from experiments made on small pipes. This loss for larger pipes is undoubtedly less.

Where

R = Radius of curvature

d = diameter of pipe

$\frac{\frac{1}{2}d}{R}$ = .1 .2 .3 .4 .5 .6 .7 .8 .9 .1

for these values n equals

.13, .14, .16, .21, .29, .44, .66, .98, 1.41, 1.98

LOSS OF PRESSURE DUE TO ENLARGEMENT OF SECTION.

When a section of pipe is enlarged as shown in fig. 14, and the pipe is kept constantly full of water, a loss of head or pressure results. From Bernoulli's theorem the pressure head plus the velocity head at any point in a line of pipe is equal to the pressure head plus the velocity head at any other section in the line, if no losses occur.

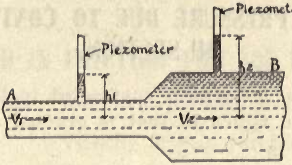


FIG. 14

Let V_1 equal the velocity and h_1 equal the pressure head at section A and V_2 equal the velocity and h_2 equal the pressure head at section B, then according to Bournellies theorem

$$h_1 + \frac{V_1^2}{2g} = h_2 + \frac{V_2^2}{2g}$$

but as the second effective head is always smaller than the first their difference is the loss of head due to enlargement of pipe.

Loss of head due to enlargement =

$$\left(h_1 + \frac{V_1^2}{2g}\right) - \left(h_2 + \frac{V_2^2}{2g}\right)$$

$$= h_1 + \frac{V_1^2}{2g} - h_2 - \frac{V_2^2}{2g} = \frac{V_1^2 - V_2^2}{2g} - (h_2 - h_1)$$

This is a general expression giving the loss due not only to enlargement but to all resistances between any two sections of a pipe.

Another form which is probably more convenient for practical use is

Loss of head due to enlargement = $\left(\frac{a_2}{a_1} - 1\right)^2 \frac{V_2^2}{2g}$

when a_1 and a_2 are the areas of the small and large sections,

LOSS OF PRESSURE DUE TO CONTRACTION OF SECTION.

When a section of pipe is contracted in the direction of flow as shown in figure 15 that is gradual contraction the loss of pressure is

$$\text{Loss due to contraction} = \frac{V_1^2 - V_2^2}{2g} + h_1 - h_2$$

$$\text{also} \quad \cdot = \left(\frac{a^2}{a_1^2} - 1\right) \frac{V_2^2}{2g} + h_1 - h_2$$

in which V_1 and V_2 are the velocities, h_1 and h_2 the pressure heads and a and a_1 the areas.

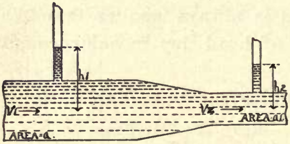


FIG. 15

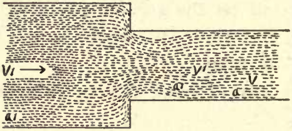


FIG. 16

For sudden contraction of section as shown in fig. 16.

$$\text{The loss due to contraction} \quad \left(\frac{1}{C} - 1\right)^2 \frac{V^2}{2g}$$

in which C is the coefficient of contraction and equal to the area $\frac{a_1}{a}$ the value of C varies from .62 to 1. For an average .65 may be used.

The loss of pressure through valves and other fittings can only be determined by experiment. An instrument for measuring these losses is described in the chapter on Measurement of Water and instruments used.

LOSS OF HEAD IN FRICTION FOR 100 FEET OF PIPE.

Diameter in Feet	Velocity in Feet per Second.						
	1	2	3	4	6	10	15
	Feet	Feet	Feet	Feet	Feet	Feet	Feet
0.05	1.46	5.10	10.3	16.9	34.7		
0.1	0.59	1.99	4.20	6.97	14.5	37.3	
0.25	.20	0.70	1.46	2.49	5.37	13.7	29.4
0.5	.09	0.32	0.70	1.14	2.46	6.22	13.3
0.75	.05	.21	.45	0.73	1.57	3.94	8.40
1.	.04	.15	.32	.55	1.12	2.80	5.95
1.25	.03	.11	.25	.42	0.85	2.11	4.48
1.5	.02	.09	.20	.33	.67	1.66	3.50
1.75	.02	.07	.16	.26	.54	1.33	2.80
2.	.02	.06	.13	.21	.45	1.09	2.27
2.5	.01	.05	.10	.16	.34	0.81	1.68
3.	.01	.04	.07	.12	.26	.67	1.40
3.5	.01	.03	.06	.10	.21	.53	
4.	.01	.02	.05	.08	.17	.42	
5.	.00	.02	.04	.06	.13		
6.	.00	.01	.03	.05	.10		

FRICTION OF WATER IN WROUGHT IRON PIPES.

Frictional Heads at Given Rates of Discharge in Clean Wrought Iron Pipe (Inside Diam.) for Each 100 Feet of Length.

U. S. Gal. per Minute	U. S. Gal. per 24 Hours	¾ In. Pipe Friction hd. Feet	¾ In. Pipe Friction hd. Lbs.	1 In. Pipe Friction hd. Feet	1 In. Pipe Friction hd. Lbs.	1¼ In. Pipe Friction hd. Feet	1¼ In. Pipe Friction hd. Lbs.	1½ In. Pipe Friction hd. Feet	1½ In. Pipe Friction hd. Lbs.	2 In. Pipe Friction hd. Feet	2 In. Pipe Friction hd. Lbs.	2½ In. Pipe Friction hd. Feet	2½ In. Pipe Friction hd. Lbs.	3 In. Pipe Friction hd. Feet	3 In. Pipe Friction hd. Lbs.
5	7200	7.59	3.30	1.93	.84	.71	.31	.27	.12	......	......	......	......	......	......
10	14400	29.90	13.00	10.26	3.16	2.41	1.05	1.08	.47	......	......	......	......	......	......
15	21600	66.01	28.70	16.05	6.98	5.47	2.38	2.23	.97	......	......	......	......	......	......
20	28800	115.92	50.40	28.29	12.30	9.36	4.07	3.81	1.66	......	......	......	......	......	......
25	36000	......	......	43.70	19.00	14.72	6.40	5.02	2.62	1.18	.51	......	......	......	......
30	43200	......	......	63.25	27.50	21.04	9.15	8.62	3.75	2.09	.91	......	......	......	......
35	50400	......	......	85.10	37.00	28.52	12.40	11.61	5.05	2.76	1.20	......	......	......	......
40	57600	......	......	110.40	48.00	37.03	16.10	14.99	6.52	3.68	1.60	1.19	.52	......	......
45	64800	......	......	......	......	46.46	20.20	18.74	8.15	4.60	2.00	1.49	.65	......	......
50	72000	......	......	......	......	57.27	24.90	23.00	10.00	5.61	2.44	1.86	.81	.80	.35
75	108000	......	......	......	......	129.00	56.10	51.52	22.40	12.23	5.32	4.14	1.80	1.70	.74
100	144000	......	......	......	......	......	......	89.70	39.00	21.75	9.46	7.36	3.20	3.01	1.31
125	180000	......	......	......	......	......	......	......	......	34.27	14.90	11.24	4.89	4.57	1.99
150	216000	......	......	......	......	......	......	......	......	48.76	21.20	16.10	7.00	6.55	2.85
175	252000	......	......	......	......	......	......	......	......	64.63	28.10	21.75	9.46	8.85	3.85
200	288000	......	......	......	......	......	......	......	......	86.25	37.50	28.68	12.47	11.54	5.02
250	360000	......	......	......	......	......	......	......	......	......	......	45.21	19.66	17.84	7.76
300	432000	......	......	......	......	......	......	......	......	......	......	64.53	28.06	25.76	11.20
350	504000	......	......	......	......	......	......	......	......	......	......	......	......	34.96	15.20
400	576000	......	......	......	......	......	......	......	......	......	......	......	......	44.85	19.50
450	648000	......	......	......	......	......	......	......	......	......	......	......	......	57.50	25.00
500	720000	......	......	......	......	......	......	......	......	......	......	......	......	70.84	30.80

FRICTION OF WATER IN CAST IRON PIPES.

Friction Heads in Clean Cast Iron Pipes for Each 1,000 Feet of Length.

U. S. Gal. per Minute	U. S. Gal. per 24 Hours	4 In. Pipe Friction hd.		5 In. Pipe Friction hd.		6 In. Pipe Friction hd.		8 In. Pipe Friction hd.		10 In. Pipe Friction hd.		12 In. Pipe Friction hd.		14 In. Pipe Friction hd.	
		Feet	Lbs.	Feet	Lbs.	Feet	Lbs.	Feet	Lbs.	Feet	Lbs.	Feet	Lbs.	Feet	Lbs.
50	72000	2.01	.87	.67	.29	.32	.14	......	......	......	......	......	......	......	......
100	144000	7.36	3.19	2.61	1.14	1.08	.47	......	......	......	......	......	......	......	......
125	180000	12.19	5.30	4.07	1.77	1.68	.73	......	......	......	......	......	......	......	......
150	216000	16.05	6.95	5.36	2.34	2.28	.99	......	......	......	......	......	......	......	......
200	288000	28.09	12.17	10.32	4.48	3.92	1.70	1.01	.44	......	......	......	......	......	......
250	360000	43.47	18.83	16.24	7.08	6.00	2.60	1.52	.66	......	......	......	......	......	......
300	432000	62.20	26.94	23.40	10.20	8.52	3.69	2.13	.92	.75	.32	......	......	......	......
400	516000	109.68	47.50	42.52	18.52	14.89	6.45	3.68	1.59	1.27	.55	......	......	......	......
500	720000	170.53	73.87	64.90	28.20	23.01	9.97	5.64	2.44	1.93	.84	......	......	......	......
600	864000	......	......	90.20	39.30	32.89	14.25	8.03	3.48	2.72	1.18	.81	.35	.40	.17
700	1008000	......	......	126.90	55.10	44.54	19.08	10.83	4.69	3.66	1.58	1.14	.49	.55	.24
800	1152000	......	......	......	......	57.95	25.10	14.05	6.08	4.73	2.05	1.52	.66	.73	.32
900	1290000	......	......	......	......	73.12	31.67	17.68	7.69	5.93	2.57	1.96	.85	.94	.41
1000	1440000	......	......	......	......	90.05	38.99	21.74	9.41	7.28	3.15	2.45	1.06	1.17	.51
1200	1728000	......	......	......	......	......	......	31.10	13.47	10.38	4.50	3.00	1.30	1.43	.62
1400	2016000	......	......	......	......	......	......	42.13	18.25	14.02	6.07	4.26	1.85	2.02	.88
1600	2304000	......	......	......	......	......	......	54.84	23.75	18.22	7.89	5.74	2.49	2.72	1.18
1800	2592000	......	......	......	......	......	......	69.22	29.98	22.96	9.95	7.44	3.22	3.51	1.52
2000	2880000	......	......	......	......	......	......	85.27	36.93	28.25	12.34	9.36	4.06	4.41	1.91
2500	3600000	......	......	......	......	......	......	......	......	43.87	19.00	11.50	5.00	5.41	2.34
3000	4320000	......	......	......	......	......	......	......	......	62.92	27.25	17.82	7.72	8.35	3.62
3500	5040000	......	......	......	......	......	......	......	......	......	......	25.51	11.05	11.93	5.17
4000	5760000	......	......	......	......	......	......	......	......	......	......	34.58	14.98	16.14	6.99
4500	6480000	......	......	......	......	......	......	......	......	......	......	......	......	21.00	9.10
														26.49	11.47

FRICTION OF WATER IN CAST IRON PIPES—Cont.

Friction Heads in Clean Cast Iron Pipes for Each 1,000 Feet of Length.

U. S. GAL. PER MINUTE	U. S. GAL. PER 24 HOURS	16 In. Pipe Friction hd. Feet	16 In. Pipe Friction hd. Lbs.	18 In. Pipe Friction hd. Feet	18 In. Pipe Friction hd. Lbs.	20 In. Pipe Friction hd. Feet	20 In. Pipe Friction hd. Lbs.	24 In. Pipe Friction hd. Feet	24 In. Pipe Friction hd. Lbs.	30 In. Pipe Friction hd. Feet	30 In. Pipe Friction hd. Lbs.	36 In. Pipe Friction hd. Feet	36 In. Pipe Friction hd. Lbs.	42 In. Pipe Friction hd. Feet	42 In. Pipe Friction hd. Lbs.
500	720000	.22	.09	......	......	......	......	......	......	......	......	......	......	......	......
600	864000	.76	.34	.44	.19	......	......	......	......	......	......	......	......	......	......
700	1008000	1.63	.71	.93	.40	.56	.24	......	......	......	......	......	......	......	......
800	1152000	2.28	1.22	1.60	.69	.96	.42	.41	.18	......	......	......	......	......	......
900	1290000	4.34	1.88	2.45	1.06	1.47	.64	.62	.27	......	......	......	......	......	......
1000	1440000	6.19	2.68	3.48	1.51	2.09	.90	.87	.38	.30	.13	......	......	......	......
1200	1728000	8.37	3 63	4.70	2.03	2.81	1.22	1.16	.50	.40	.17	......	......	......	......
1400	2016000	10.87	4.71	6.09	2.64	3.64	1.58	1.50	.65	.52	.22	......	......	......	......
1600	2304000	13.70	5.93	7.67	3.32	4.58	1.98	1.88	.82	.64	.28	......	......	......	......
1800	2592000	16.85	7.30	9.43	4.08	5.62	2.43	2.31	1.00	.78	.34	.33	.14	......	......
2000	2880000	......	......	13.49	5.84	8.03	3.48	3.28	1.42	1.11	.48	.46	.20	......	......
2500	3600000	......	......	......	......	10.86	4.71	4.43	1.92	1.49	.65	.62	.27	......	......
3000	4320000	......	......	......	......	......	......	5.75	2.49	1.93	.84	.80	.35	......	......
3500	5040000	......	......	......	......	......	......	7.25	3.14	2.43	1.05	1.00	.43	......	......
4000	5760000	......	......	......	......	......	......	......	......	2.98	1.29	1.23	.53	.63	.27
4500	6480000	......	......	......	......	......	......	......	......	3.59	1.55	1.47	.64	.76	.33
5000	7200000	......	......	......	......	......	......	......	......	4.25	1.84	1.74	.75	.91	.40
6000	8640000	......	......	......	......	......	......	......	......	4.97	2.15	2.03	.88	1.09	.47
7000	10080000	......	......	......	......	......	......	......	......	5.75	2.49	2.35	1.02	1.25	.54
8000	11520000	......	......	......	......	......	......	......	......	6.58	2.85	2.69	1.17	1.43	.62
9000	12960000	......	......	......	......	......	......	......	......	......	......	3.04	1.32	1.62	.71
10000	14400000	......	......	......	......	......	......	......	......	......	......	3.43	1.49	1.84	.80
11000	15840000	......	......	......	......	......	......	......	......	......	......	3.83	1.66	2.07	.90
12000	17280000	......	......	......	......	......	......	......	......	......	......	4.71	2.04	2.55	1.11

LOSS OF PRESSURE CAUSED BY VALVES AND FITTINGS.

The data given below is condensed from the results of experiments made at different times by the Inspection Department of the Associated Factory Mutuals Fire Insurance Companies. The friction losses in ells and tees are approximate, but, since fittings of the same nominal size with the different curvatures and different smoothness as made by different manufacturers will cause materially different friction losses, the figures below will give a fair indication of what loss may be expected from the several fittings.

NAME OF FITTING.	Number of feet of clean, straight pipe of same size which would cause the same loss as the fitting.
6-inch Grinnell Dry-Pipe Valve*	80
4-inch Grinnell Dry-Pipe Valve*..........	47
6-inch Grinnell Alarm Check.............	100
4-inch Grinnell Alarm Check.............	47
6-inch Pratt & Cady Check Valve.........	50
6-inch Walworth Globe Check Valve......	200
4-inch Pratt & Cady Check Valve.........	25
4-inch Walworth Globe Check Valve.......	130
2½-inch to 8-inch Long-Turn Ells........	4
2½-inch to 8-inch Short-Turn Ells........	9
3-inch to 8-inch Long-Turn Tees..........	9
3-inch to 8-inch Short-Turn Tees.........	17
⅛-bend	5

* Differential type.

LOSS OF PRESSURE CAUSED BY METER.

LOSS OF PRESSURE IN POUNDS DUE TO METER.

Gallons per Min. Flowing through Meter	Current Meters		Disc Meters		Rotary Piston			Current		Proportional			Piston	
	4 In. Gem	4 In. Torrent	4 In. Lambert	6 In. Trident	4 In. Crown	4 In. Hersey	4 In. Union	6 In. Gem	8 In. Torrent	6 In. By-Pass 2 In. Crown	6 In. Check 2 In. Crown	4 In. By-Pass 1½ In. Crown	3 In. Worthington	6 In. Worthington
50	......	......	......	......	0.3	0.5	......	......	......	......	0.1	0.1	1.6	0.2
100	......	0.2	0.6	0.1	1.4	1.6	0.2	......	......	......	0.1	0.2	6.0	0.3
200	0.8	1.3	2.2	0.3	4.9	6.1	1.1	......	......	......	0.2	0.5	23.0	0.9
250	1.1	2.0	3.4	0.4	7.5	9.3	1.7	......	......	0.1	0.3	0.8	34.8	1.4
300	1.6	2.9	4.8	0.5	10.9	13.3	2.5	0.4	0.3	0.1	0.4	1.1	48.0	1.8
400	2.7	5.1	8.2	1.0	19.9	25.1	4.2	0.8	0.5	0.2	0.6	1.9	......	3.2
500	4.1	8.1	12.9	1.6	31.2	40.0	6.4	1.1	0.7	0.3	0.8	2.9	......	4.9
600	6.1	11.9	18.7	2.2	......	......	9.4	1.7	1.0	0.5	1.1	4.4	......	7.1
700	8.3	16.4	25.1	3.0	......	......	12.8	2.3	1.3	0.7	1.5	6.1	......	9.5
750	9.5	18.9	28.6	3.5	......	......	14.6	2.6	1.6	0.7	1.7	7.2	......	10.8
800	10.8	21.4	......	4.0	......	......	16.6	3.0	1.8	0.9	2.0	8.3	......	12.2
900	13.5	......	......	5.1	......	......	20.8	3.9	2.3	1.2	2.5	10.9	......	14.8
1000	......	......	......	6.4	......	......	25.5	4.8	2.8	1.4	3.0	13.9	......	17.7
1250	......	......	......	10.0	......	......	......	7.2	4.5	2.3	4.8	......	......	......
1500	......	......	......	......	......	......	......	10.0	6.4	3.1	7.1	......	......	......
1600	......	......	......	......	......	......	......	......	7.3	3.5	8.6	......	......	......
2000	......	......	......	......	......	......	......	......	......	5.6	......	......	......	......

The tests showed:

1. That all meters obstruct the flow of water to a greater or less extent, many types seriously reducing the pressure with heavy fire drafts.

2. That ordinary types of disc and piston meters may almost completely stop the flow of water if their moving parts become blocked, which is easily possible.

3. That fish traps, while lessening the danger of the moving parts becoming blocked, are liable to become seriously clogged by pipe scales, leaves, etc.

4. Therefore, meters should not be put on fire service supplies. The best way to remove a supposed need of meters is to absolutely separate the pipes carrying water for manufacturing and domestic purposes from the fire system and supply them by a separate metered connection from the public mains; then guarantee that no water will be used from the fire system except in case of fire or for occasional tests, which should be made strictly in accordance with the rules of the water department.

In the cases where some further check is considered necessary, hydrant and sprinkler drain valves may be sealed by the water department and notice promptly given when one is broken for any cause. In some such cases the meters of the "Proportional" type may be the most satisfactory check and are unobjectionable.

a. The Gem, Crown and Hersey Meters had fish traps as part of the meter, so that the losses above include the trap. The Torrent, Lambert, Union and Worthington Meters use a separate trap; they were, however, tested without traps.

b. All the meters tested, with the exception of the Worthington 3-inch, which had been used for some time, were new, clean meters.

c. The above results were obtained from tests made by the Inspection Department of the Associated Factory Mutual Fire Insurance Companies during 1896-7-8. For full data of experiments, see "Journal of N. E. W. W. Association," vol. xii., No. 2; also "Transactions American Society Mechanical Engineers," vol. xx.

PRESSURE CONSUMED IN PRODUCING VELOCITY OF WATER THROUGH PIPES.

When water moves through a pipe at a certain velocity, part of the total pressure is consumed in producing that velocity. The following is the general formulæ for computing the pressure consumed in producing velocity:

$$P_v = \frac{v^2}{2g \times 2.31} = .001148 \frac{G^2}{d^4}$$

Where

P_v =Velocity pressure lbs. per sq. inch.
v =Linear velocity. Ft. per second.
d =Diameter of pipe in inches.
G =Rate of flow. Gals. per minute.
g =Acceleration due to gravity=32.2.

PROOF.

Let h_v =velocity head in feet.

Then $h_v = \frac{v^2}{2g}$

Reducing this to pounds per sq. inch, we have

$$2.307 \ P_v = h_v = \frac{v}{2g}$$

and $$P_v = \frac{v^2}{2g \times 2.307} = \frac{v^2}{2 \times 32.2 \times 2.307} = \frac{v^2}{148.39}$$

Velocity=(length of pipe in feet holding one gallon) multiplied by (number of gallons per sec.)

Length of pipe in feet holding one gallon equals=

$$\frac{.1331}{\text{Area in square feet}}$$

then

Velocity=

$$\frac{.1331 \times (\text{gal. per sec.})}{\text{Area in square inches}} = \frac{.1331 \times (\text{gal. per min.}) \times 144}{60 \times (\text{Area in square inches})}$$

Area in square inches $\frac{\pi\, d^2}{4} = .7854 \times (\text{diameter in inches})^2$

$$\text{Velocity} = \frac{144 \times .1331 \times (\text{gal. per min.})}{60 \times .7854\,(\text{diameter in inches})^2} = c\,\frac{G^2}{d^4}$$

$$P_v = \frac{v^2}{148.39} = \frac{c^2}{148.39}\,\frac{G^2}{d^4} = \frac{(144 \times .1331)^2}{(60 \times .7854)^2 \times 148.39}\,\frac{G^2}{d^4}$$

$$P_v = .001148\,\frac{G^2}{d^4}$$

EXAMPLE.—Find the pressure in pounds per square inch consumed in producing velocity in a 1-inch pipe discharging 60 gallons of water per minute?

$$P_v = .001148\,\frac{G^2}{d^4}$$

$$P_v = .001148\,\frac{60 \times 60}{1 \times 1 \times 1 \times 1} = .001148 \times 3600$$

$P_v = 4.13$ pounds the required answer.

NOTE.—The table on page 49 is based on the Hydraulic Law that a quantity of water carried by pipes of the same length and smoothness of surface with a given loss of pressure varies as the square roots of the 5th powers of the diameters. The second column gives this function for the diameters that are printed in the first column. The remaining columns show how many pipes of the sizes printed at the top are equivalent to one pipe of the size in the first column.

EXAMPLE.—How much water will a 10-inch pipe carry as compared with a 6, with the same loss of pressure?

Follow down the first column to 10, then to the right under the column head 6 we find 3.58, which shows that a 10-inch pipe will carry 3.58 times as much water as a 6-inch.

TABLE Showing the Theoretical Velocity and Discharge in Cubic Feet Through an Orifice of 1 Square Inch Issuing Under Heads Varying From 1 to 100 Feet.

Hd. in Ft.	Theoretical Discharge in Cu. Ft. per Min.	Theoretical Velocity in Feet per Min.	Hd. in Ft.	Theoretical Discharge in Cu. Ft. per Min.	Theoretical Velocity in Feet per Min.
1	3.34	481.2	51	23.85	3436.4
2	4.73	680.4	52	24.08	3469.9
3	5.79	833.4	53	24.31	3503.1
4	6.68	962.4	54	24.54	3536.0
5	7.47	1075.8	55	24.76	3568.6
6	8.18	1178.4	56	24.99	3600.9
7	8.84	1273.2	57	25.21	3632.9
8	9.45	1360.8	58	25.43	3664.6
9	10.02	1443.6	59	25.65	3696.1
10	10.57	1521.6	60	25.87	3727.3
11	11.08	1596.0	61	26.08	3758.2
12	11.57	1666.8	62	26.29	3788.9
13	12.05	1734.6	63	26.51	3819.3
14	12.50	1800.6	64	26.72	3849.6
15	12.94	1863.6	65	26.92	3879.5
16	13.37	1924.8	66	27.13	3909.2
17	13.78	1984.2	67	27.33	3938.7
18	14.18	2041.8	68	27.54	3968.4
19	14.57	2097.6	69	27.74	3997.1
20	14.95	2152.2	70	27.94	4021.1
21	15.31	2205.0	71	28.14	4054.5
22	15.67	2256.6	72	28.34	4283.0
23	16.02	2307.6	73	28.53	4111.3
24	16.37	2357.4	74	28.73	4139.4
25	16.71	2406.0	75	28.93	4165.2
26	17.04	2453.4	76	29.11	4194.9
27	17.36	2500.2	77	29.30	4222.4
28	17.68	2545.8	78	29.49	4249.8
29	17.99	2590.8	79	29.68	4265.9
30	18.30	2635.8	80	29.87	4303.6
31	18.60	2679.0	81	30.06	4330.8
32	18.90	2722.2	82	30.24	4357.4
33	19.20	2764.2	83	30.42	4383.6
34	19.49	2806.2	84	30.61	4410.2
35	19.77	2847.6	85	30.79	4436.4
36	20.05	2887.2	86	30.97	4462.4
37	20.33	2926.8	87	31.15	4488.2
38	20.60	2966.4	88	31.33	4514.0
39	20.87	3004.8	89	31.50	4539.5
40	21.13	3043.2	90	31.68	4565.0
41	21.38	3081.1	91	31.86	4590.3
42	21.64	3118.5	92	32.04	4615.4
43	21.90	3156.4	93	32.20	4640.5
44	22.15	3191.8	94	32.38	4665.3
45	22.40	3227.8	95	32.55	4690.1
46	22.65	3263.6	96	32.72	4714.7
47	22.89	3298.9	97	32.89	4739.2
48	23.14	3333.8	98	33.06	4763.5
49	23.38	3368.4	99	33.23	4787.8
50	23.61	3402.5	100	33.40	4812.0

RELATIVE DISCHARGING CAPACITIES OF PIPES FLOWING FULL.

Taken from "A Treatise on Hydraulic and Water-Supply Engineering,"
By J. T. Fanning, C. E.

Diam. in Inches	Relative Discharging Capacities	DIAMETER IN INCHES									
d.	$\sqrt{d^5}$	3	4	5	6	8	10	12	14	16	18
48	15,963.	....	....	....	....	....	....	....	....	15.59	11.61
44	12,842.	....	....	....	....	....	....	....	17.50	12.54	9.34
40	10,119.	....	....	....	....	....	....	20.23	13.47	9.85	7.34
36	7,776.0	....	....	....	....	....	....	15.58	8.41	7.59	5.65
33	6,255.8	....	....	....	....	34.55	19.78	12.54	8.52	6.11	4.55
30	4,929.5	....	....	....	....	27.09	15.54	9.85	6.54	4.80	3.57
27	3,788.0	....	....	....	42.95	16.61	9.96	7.59	5.16	3.70	2.75
24	2,821.8	....	....	50.50	32.00	15.58	8.92	5.65	3.84	2.75	2.05
22	2,270.2	....	70.96	40.65	25.73	12.53	7.17	4.55	3.09	2.16	1.65
20	1,788.9	....	55.96	32.05	20.29	9.88	5.66	3.58	2.43	1.74	1.30
18	1,374.6	....	42.01	24.63	15.58	7.25	4.34	2.75	1.87	1.34	1
16	1,024.0	65.77	32.01	18.31	11.60	5.65	3.23	2.05	1.39	1	....
14	733.4	47.14	22.94	13.15	8.32	4.05	2.32	1.47	1	....	....
12	498.8	32.05	15.60	8.93	5.65	2.75	1.57	1	....	....	....
10	316.2	20.31	9.88	5.66	3.58	1.74	1	....	....	....	....
8	181.0	11.63	5.66	3.24	2.05	1	....	....	....	....	....
6	88.18	5.66	2.75	1.58	1	....	....	....	....	....	....
5	55.90	3.58	1.75	1	....	....	....	....	....	....	....
4	32.00	2.05	1	....	....	....	....	....	....	....	....
3	15.59	1	....	....	....	....	....	....	....	....	....

See note, page 50.

AUTOMATIC SPRINKLERS.

The idea conceived by inventors of automatic sprinklers was to create a device by means of which a fire might be arrested or extinguished in its incipiency through the agency of heat created by the fire itself. How well they have succeeded, is shown by the fire records covering a period of more than twenty years. There is no question but that the automatic sprinkler system has proven an unqualified success for the purpose for which it was created.

DESCRIPTION AND GENERAL ARRANGEMENT.

Lines of pipes are installed through the building near the ceiling from 8 to 10 feet apart, and supported by means of hangers. These lines are connected to larger pipes leading to the source of water supply. To each of these line pipes is connected at intervals from 8 to 10 feet, the automatic sprinkler head. Should a fire start at any point in the room the heat coming in contact with the fusible solder at a temperature of 160 degrees or more would instantly melt same, causing a release of the disc or valve of the sprinkler head, and the water under pressure would be forced out through the discharge orifice, striking the deflector or distributor and thereby cause the water to spray in all directions.

There are two sprinkler systems in general use. The Wet System, which is used in buildings in which there is no danger of freezing, the pipes being at all times filled with water. The Dry System, which is used where freezing is possible, the water supply being intercepted at the point where freezing might occur, by a dry pipe valve; and between this valve and the sprinkler heads the pipes are filled with compressed air at a relatively low pressure of about 30 pounds per square inch.

Figures 21 to 28, inclusive, show eight well-known Sprinkler Heads in general use at the present time. A further description of these heads is omitted owing to the fact that the manufacturers have minutely and fully described them in their catalogues, of which a liberal supply is constantly before the public.

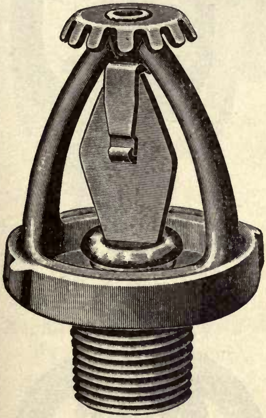


FIG. 21

THE GRINNELL.
Manufactured by The General Fire Extinguisher Company, Providence, R. I.

FIG. 22.

THE NERACHER.
Manufactured by The General Fire Extinguisher Company, Providence, R. I.

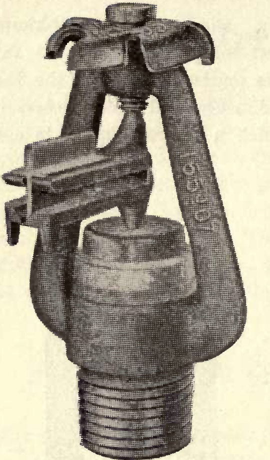


FIG. 23.

THE MANUFACTURERS.
Manufactured by Manufacturers Automatic Sprinkler Co., Syracuse, N. Y.

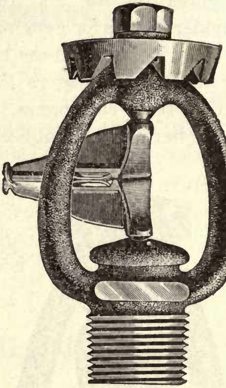


FIG. 24.

THE ESTY.
Manufactured by The Esty Sprinkler Company, Laconia, N. H.

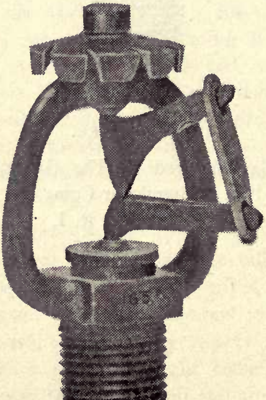


FIG. 25.

THE INTERNATIONAL.
Manufactured by The International Sprinkler Company, Philadelphia, Pa.

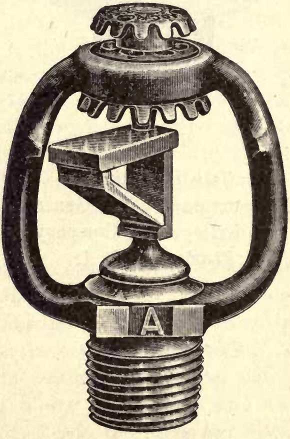


FIG. 26.

THE ROCKWOOD.
Manufactured by The Worcester Fire Extinguisher Company, Worcester, Mass.

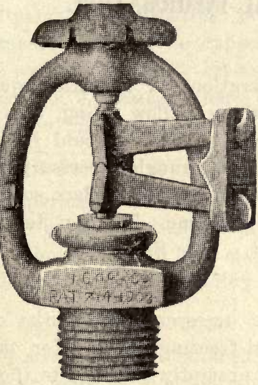


FIG. 27

THE NIAGARA.

Manufactured by Niagara Fire Extinguisher Company, Akron, Ohio.

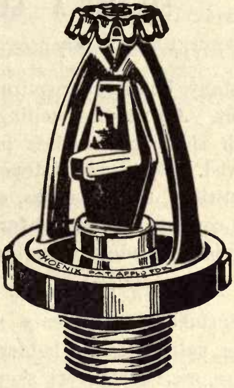


FIG. 28

THE PHOENIX.

Manufactured by The Phoenix Fire Extinguisher Company, Chicago, Ill.

NATIONAL BOARD SPRINKLER RULES.
SECTION A—GENERAL INFORMATION.

1. *Preparation of Building.*

Many buildings require preparation for sprinkler equipment. All needless ceiling sheathing, hollow siding, tops of high shelving, needless partitions or decks should be removed. Necessary "stops" to check draught, necessary new partitions, closets, decks, etc., should be put in place so that the equipment may conform to the same. The top flooring should be made thoroughly tight. (See Sec. B4.)

2. *Accessory Woodwork.*

Sprinkler equipments require accessory woodwork, dry pipe valve closets, ladders, anti-freezing boxing for tank pipes, etc. This work should be promptly attended to if not let with sprinkler contract.

3. *Drapery and Sheathing.*

Paper or similar light inflammable ceiling sheathing is objectionable and unnecessary. Where floors leak dirt, an acceptable sheathing may be made of lath and plaster, matched boards or joined metal. All channels back of sheathing to be thoroughly closed between timbers or joists. Sheathing to be tightly put together and kept in repair. In mill bays, sheathing to follow contour of timbers without concealed space.

4. *Vertical Draughts.*

Vertical draughts through buildings are detrimental to the proper action of sprinklers and should be "stopped" where practicable.

5. *Clear Space Below Ceilings.*

Full, effective action of sprinklers requires about 24 inches wholly clear space below roofs or ceilings; this loss of storage capacity should be realized in advance of equipment.

6. *Experienced Workmen Recommended.*

Sprinkler installation is a trade in itself. Insurance inspectors cannot be expected to act as working superintendents, nor correct errors of beginners. Sprinkler work should be entrusted to none but fully experienced and responsible parties.

7. *All Portions of Buildings to be Protected.*

Experience teaches that sprinklers are often necessary where seemingly least needed. Their protection is required not alone where a fire may begin, but also wherever any fire might extend, including wet or damp locations.

8. *Degree of Protection.*

A maximum protection cannot be expected where sprinklers are at more or less permanent disadvantage, as in the case of stocks very susceptible to smoke and water damage, buildings having deep piles of hollow goods, excessive draughts, explosion or flash fire hazards, or large amounts of benzine or similar fluid.

9. *Curtain Boards.*

Where two or more floors of a building communicate by openings not provided with approved "stops," acceptable curtain boards or cornices, wide enough to bank up the heated air at least 6 inches below the fusible device of the sprinklers, should be fitted around the openings at each floor.

10. *Necessary Cut-offs.*

Sprinklers cannot be expected to keep out fire originating in unsprinkled territory. Stringent measures should be used to properly cut off all unsprinkled portions of buildings or exposures.

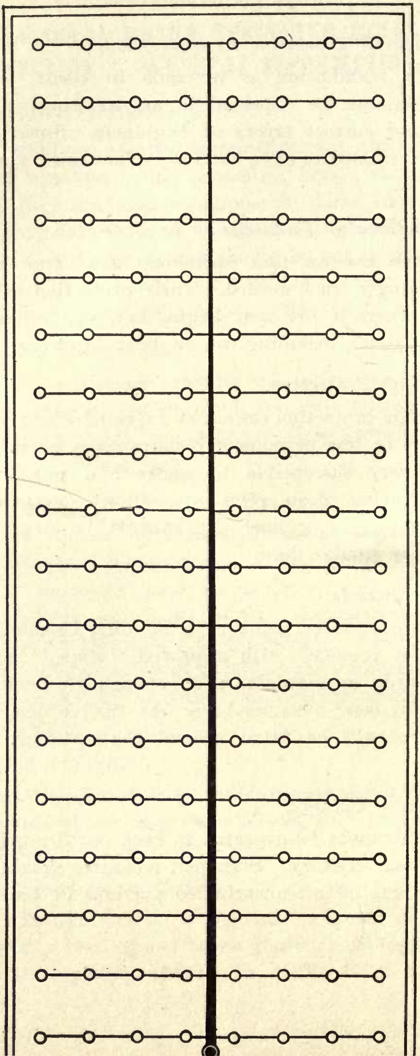


Fig. 17.

End Central Feed to Automatic Sprinklers.

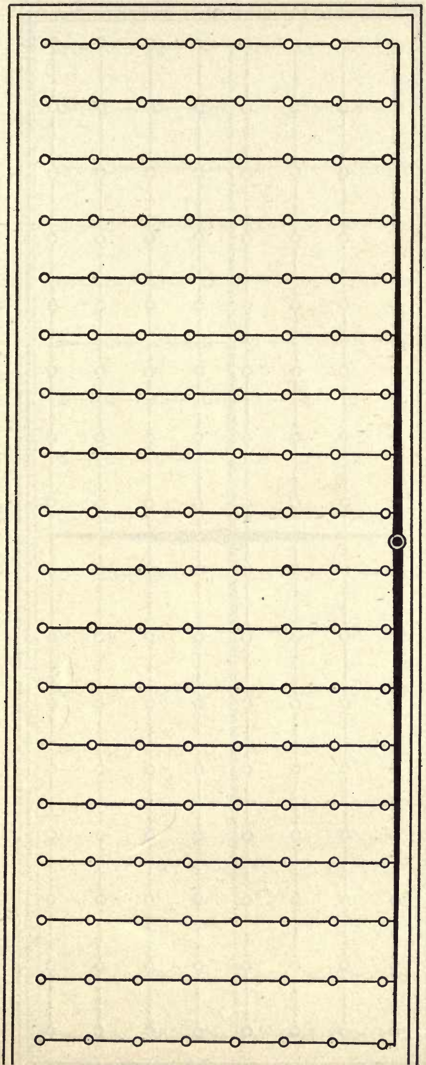


Fig. 18

Side Central Feed to Automatic Sprinklers.

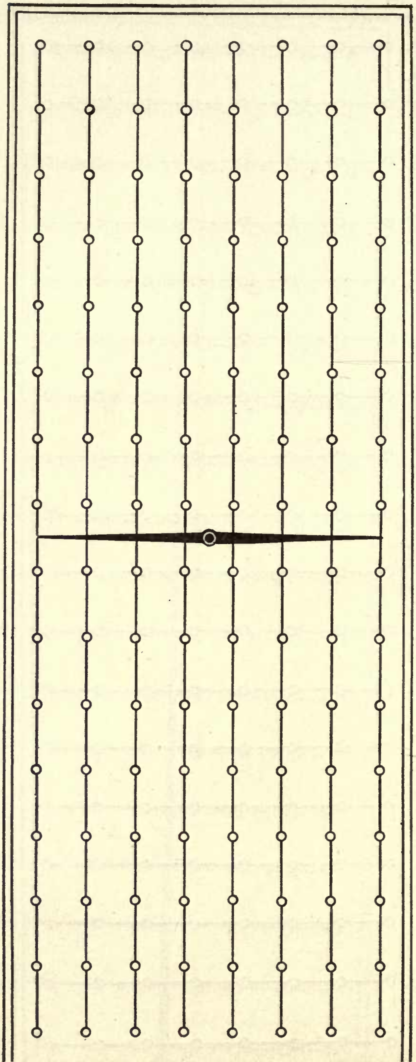


FIG. 19.

ACROSS CENTER FEED TO AUTOMATIC SPRINKLERS.

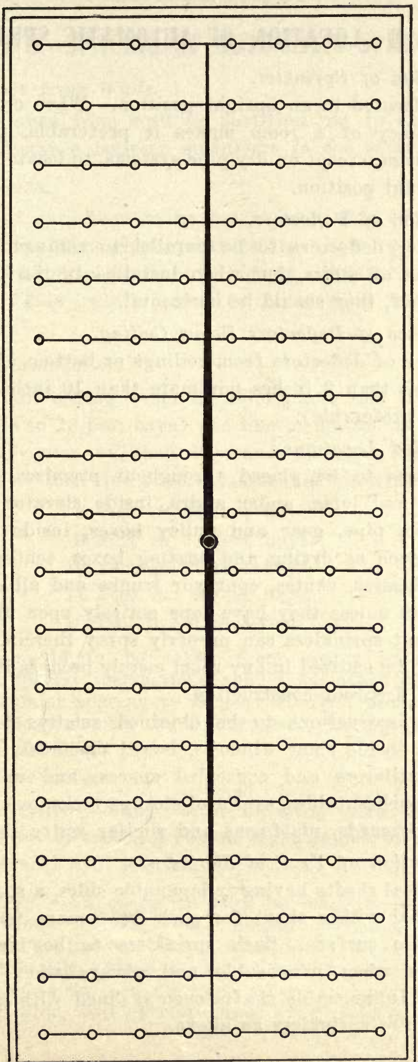


Fig. 20.
Center Central Feed to Automatic Sprinklers.

SECTION B—LOCATION OF AUTOMATIC SPRINKLERS.

1. *Position of Sprinkler.*

To be located in an upright position. When construction or occupancy of a room makes it preferable, permission may be given, except on dry-pipe systems, to locate sprinklers in a pendant position.

2. *Position of Deflectors.*

Sprinkler deflectors to be parallel to ceilings, roofs, or the incline of stairs, but when installed in the peak of a pitched roof, they should be horizontal.

3. *Distance of Deflectors Below Ceiling.*

Distance of deflectors from ceilings or bottom of joists to be not less than 3 inches nor more than 10 inches (6 to 8 inches is preferable).

4. *Detailed Locations.*

Sprinklers to be placed throughout premises, including basement and lofts, under stairs, inside elevator wells, in belt, cable, pipe, gear and pulley boxes, inside small enclosures, such as drying and heating boxes, tenter and dry room enclosures, chutes, conveyor trunks and all cupboards and closets unless they have tops entirely open and are so located that sprinklers can properly spray therein. Sprinklers not to be omitted in any room merely because it is damp, wet or of fireproof construction.

Special instructions to be obtained relative to placing sprinklers inside show windows, boxed machines, metal air ducts, ventilators and concealed spaces, and under large shelves, benches, tables, overhead storage racks, over dynamos and switchboards, platforms and similar water sheds.

5. *Protection of Vertical Shafts.*

In vertical shafts having inflammable sides, a sprinkler to be provided within shaft for each 200 square feet of the inflammable surface. Such sprinklers to be installed at each floor when practicable and always when shaft is trapped. Inflammable shafts even if lined with plaster or metal require sprinklers as above.

SECTION C—SPACING OF AUTOMATIC SPRINKLERS.

1. *Distance from Walls.*

The distance from wall or partition not to exceed one-half the distance between sprinklers in the same direction

2. *Partitions.*

A line of sprinklers to be run on each side of partition. Cutting holes through a partition to allow sprinklers on one side thereof to distribute water to the other side is not effectual. This rule applies to both solid and slatted partitions.

3. *Mill Construction.*

Under mill ceiling (smooth, solid plank and timber construction, 6 to 12-feet bays) one line of sprinklers should be placed in center of each bay and distance between the sprinklers on each line not to exceed the following:

8 feet in 12-feet bays.
9 feet in 11-feet bays.
10 feet in 10-feet bays.
11 feet in 9-feet bays.
12 feet in 6 to 8-feet bays.

Measurements to be taken from center to center of timbers. Special instructions should be asked where rule allows sprinkler spacing to be over 10 feet, because special conditions may require the Underwriters having jurisdiction to modify the rule.

4. *Joisted Ceilings.*

Under joisted ceiling, open finished, distance between sprinklers not to exceed 8 feet at right angles with joists or 10 feet parallel with joists.

Exception.—An exception may be made to this rule if the conditions warrant, viz., special permission may be given to install but one line of sprinklers in bays 10 to 11½ feet wide from center to center of the timbers which support the joists. In all cases where such bays are over 11½ feet wide, two or more lines of sprinklers should be

installed in each bay as required by the rules for spacing. This does not apply where beams are flush with the joists, in which case sprinklers may be spaced as called for in the Rule 4. Where permission is given, the sprinklers should be placed closer together on a line so that in no case will the area covered by a single sprinkler exceed 80 square feet. Also see Rule 8.

5. *Smooth Sheathed or Plastered Ceilings.*

Under smooth sheathed or plastered ceilings, in bays 6 to 12 feet wide (measurement to be taken from center to center of timber, girder or other protection or support forming the bay), one line of sprinklers to be placed in center of each bay, and distance between the sprinklers on each line not to exceed the following: 8 feet in 12-feet bays; 9 feet in 11-feet bays; 10 feet in 6 to 10-feet bays. Bays in excess of 12 feet width and less than 23 feet width to contain at least two lines of sprinklers; bays 23 feet in width or over to have the lines therein not over 10 feet apart. In bays in excess of 12 feet width, not more than 100 square feet ceiling area to be allotted any one sprinkler.

6. *Pitched Roofs.*

Under a pitched roof sloping more steeply than 1 foot in 3, one line of sprinklers to be located in peak of roof, and sprinklers on either side to be spaced according to above requirements. Distance between sprinklers to be measured on a line parallel with roof. Where the roof meets the floor line there should be a line of sprinklers placed not over 3½ feet from where roof timbers meet floor.

Two lines of sprinklers not more than 2½ feet distant each way from the peak of roof, measured on a line with the roof, may be used in lieu of one line of sprinklers located in peak of roof Also see Rule 8.

7. *Staggered Spacing.*

Under open finish, joisted construction floors, decks and roofs, the sprinklers should be "staggered" spaced so that heads will be opposite a point half-way between sprinklers

on adjacent lines, the end heads on alternate lines to be not more than 2 feet from wall of partition. Also see Rule 1.

This regulation does not except sprinklers within a bay, whether on one, two or more lines. Adjacent sprinklers to be so staggered as not to distribute water into the same joist channel ways. Special instruction to be obtained in each case as to whether staggered spacing shall be required under open joist construction, where the channel spaces between joists are positively blocked off within the territory of any two adjacent sprinklers.

8. *Unusual Construction.*

Special instructions to be obtained from underwriters having jurisdiction relative to location of sprinklers under floors and roofs of panel or other unusual construction which may interfere with distribution of water and for which provision is not hereinbefore made.

SECTION D—PIPE SIZES.

1. *General Schedule.*

In no case should the number of sprinklers on a given size pipe exceed the following:

Size of Pipe.	Maximum No. of Sprinklers Allowed.
¾-inch	1 sprinkler
1 "	2 "
1¼ "	3 "
1½ "	5 "
2 "	10 "
2½ "	20 "
3 "	36 "
3½ "	55 "
4 "	80 "
5 "	140 "
6 "	200 "

Where practicable, it is desirable to arrange the piping so that the number of sprinklers on a branch line will not exceed eight. Care should be taken to ream out all burr at the ends of each length of pipe. This is of particular importance where the piping is cut by means of wheel cutters.

SECTION E—FEED MAINS AND RISERS.

1. *Location of Feed Pipe.*

"Center central" or "side central" feed to sprinklers is recommended. The former is preferred, especially where there are over six sprinklers on a branch line. End feed is not approved. (See illustrations.)

2. *Size of Risers.*

There should be one or more separate risers in each building and in each section of the building divided by fire walls. The size of each riser to be sufficient to supply all the sprinklers on any one floor, as determined by the standard schedule of pipe sizes. If the conditions warrant, special permission will be granted allowing the sprinklers in a fire section of small area (total number of sprinklers not to exceed forty-eight per floor) to be fed from the riser in another section.

Stair or other towers without approved stops between floors, if piped on independent riser, to be treated as one room with reference to pipe sizes, *i. e.*, feed main to tower to be of sufficient size to accommodate the total number of sprinklers in the tower.

3. *Connections to Systems.*

All main water supplies to connect with sprinkler system at foot of riser.

Exception.—Where a gravity or pressure tank, or both, constitute the only automatic source of water supply, special permission may be given to connect the tank or tanks with the sprinkler system at the top of the riser, provided lower level control to several fire sections is not required.

SECTION F—VALVES AND FITTINGS.

1. *Types of Valves to be Used.*

All valves on connections to water supplies and in supply pipes to sprinklers to be of approved outside screw and yoke or other approved indicator pattern. Check valves to be of approved straight-way pattern, to be installed in horizontal pipe, unless suitably designed for vertical position.

Underground gate valves of approved pattern equipped with approved indicator posts fulfill this rule.

2. *Valves in Connection to Water Supply.*

The pipe connecting each source of water supply with the sprinkler system to be provided with a gate and a check valve. The gate valve to be located close to the supply, as at the tank, or near base of tank trestle, pump, or in the pipe connecting the riser with the water works system, and the check valve to be located in the lower level when the water supplies are connected at foot of riser.

Where tanks are connected to the top of riser, both gate and check valves would be located in the connections at this level. (See Section E, exception to Rule 3.)

When the gate and check valve required for any one supply can be located near each other without conflicting with the above rule it is generally preferable to locate the check valve nearer the water supply than the gate valve, this so that it may be possible to examine or repair the check valve and at the same time keep other water supplies and the system itself in service.

3. *Check or Gate Valve on Pump or Tank Discharge.*

When a pump, not located in a non-combustible pump house, or exposed to danger from fire or falling walls, or a tank discharges into a yard main fed by another supply, a check valve or post gate valve should be placed in this discharge pipe at a safe distance outside the building, underground.

Check valves on tank connections may be placed inside buildings, when located underground and at a safe distance from the tank riser.

4. *Valves in Supply Pipes to Sprinklers.*

Each system to be provided with a gate valve so located as to control all sources of water supply except that from steamer connections. All gate valves controlling automatic water supplies for sprinklers should be located where easily visible and readily accessible.

5. *Indicator Posts for Gate Valves.*

Where sprinklers are supplied from yard main, place, if possible, an approved outside post indicator gate valve in connecting pipe at safe distance from building (say, 40 feet).

6. *Pit for Underground Check Valves.*

Each underground check valve to be located in a pit accessible through a manhole. Pit to be tight enough to keep out water from the ground or surface and to be provided with a deck, forming a double air space, to prevent freezing.

7. *Straps.*

All gate valves in supply pipes to automatic sprinklers, whether or not of indicator or post pattern, to be kept secured open with padlocked or riveted leather straps. Draw-off valves to be secured closed. An exception to this rule may be made only where a reliable system is maintained for permanently sealing all valves and for immediate notification of broken seals.

8. *Fittings.*

Long bend fittings are recommended.

9. *Hangers.*

Pipes to be supported in a substantial manner by wrought or cast-iron hangers well secured.

10. *Test Pipe.*

On wet systems, there should be a test pipe ½ inch in diameter connected directly with each riser in upper story and arranged to discharge outside building.

11. *Drip Pipes.*

Drip pipes to be provided to drain all parts of the system. Drip pipes at main risers to be not smaller than two (2) inches, and when exposed to the weather to be fitted with hood or down-turned elbow to prevent stoppage with ice.

12. *Drainage.*

All sprinkler pipe and fittings to be so installed that they can be thoroughly drained, and, where practicable, all piping to be arranged to drain at the main drips. On wet pipe systems the horizontal branch pipes to be pitched not less than ¼ inch in 10 feet. (See also Sec. H 2.)

13. *Pressure Gages.*

A standard make—5-inch dial, spring, pressure gage to be connected with the discharge pipe from each water supply, including the connecting pipe from public water works, and also as follows:

With each sprinkler system above and below the alarm check or dry pipe valve.

At the air pump supplying the pressure tank.

At the pressure tank.

In each independent pipe from air supply to dry pipe systems.

Gages to be located in a suitable place, and where water will not freeze, each to be controlled by a cock valve having a square head for wrench. A plugged tee or pet cock to be located between each cock and gage.

DISCHARGE OF WATER FROM A "BRANCH LINE" OF SIX OPEN PENDANT SPRINKLERS.

As Determined by Test Made by The Underwriters' Bureau of New England, April 17, 1896.

Pipe sizes and sprinkler orifices as recently suggested by the New York conference, *i. e.:*

Pipe Schedule.

One sprinkler on ¾-inch pipe, 2 on 1-inch, 4 on 1¼-inch, 8 on 1½-inch.

Orifice.

The equivalent of an opening ½ inch in diameter cut in a thin plate.

With pressures varying from 5 to 40 pounds at the up-stream sprinkler (these were the pressures used in test) it was found that the pressure at down-stream or end sprinkler is slightly less than one-half the pressure at up-stream sprinkler.

It was found that between these same limits of pressure there is practically no variation in the proportionate amount of water discharged by each of the six sprinklers. The up-stream sprinkler discharges 20 per cent. of the total amount; the second sprinkler, 18 per cent.; third, 17 per cent.; fourth, 16.5 per cent.; fifth, 15.5 per cent.; sixth, or end sprinkler, 13 per cent.; *i. e.,* the down-stream sprinkler, all six sprinklers being open, discharges 65 per cent. as much water as the up-stream sprinkler.

Total volume of water discharged by the six sprinklers is as follows:

Pounds Pressure at Up-Stream Sprinkler.	Gallons Discharged Per minute.
5	62
10	88
15	109
30	145
40	178

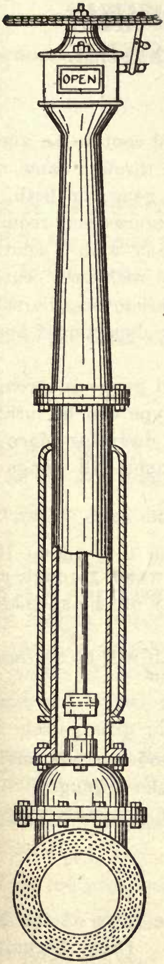


FIG. 29.

INDICATOR POST VALVES.

Figure 29 shows a standard form of indicator post. The object of the indicator post is to provide means for operating underground valves and furnishing a positive indicator, showing whether the valves are open or closed. They are used principally in factory and mill yards in connection with the fire protection service, but may, with advantage, be used at any point where the valve is underground. The use of an indicator post does away with the annoyance and delay of searching for a valve box which may be covered with snow or dirt. The device consists of a strong, cast-iron tubular adjustable post made in two sections, projecting about 32 inches above the ground and extending below the surface where it is fastened to the valve by studs of the stuffing box. The stem of the valve is joined to the square operating rods either by a collar, to which the ½-inch bronze pin passes, or by a strong, malleable iron clamp made in two pieces and clamped together with bolts.

Turning the hand wheel to the left opens the valve, and exposes the word "OPEN" at glass indicator turning to the right closes the valve and exposes the word "SHUT."

NATIONAL BOARD SPRINKLER RULES.
SECTION G—ALARM VALVE SYSTEM.

1. *Gongs and Connections.*

Every automatic sprinkler system should contain an alarm valve so constructed that a flow of water through same will operate an electric gong, a mechanical gong, or both, as the character of the property and circumstances may require. In cities where there is an alarm company with a central station, the alarm valve may be connected with such central station. In other places, especially in small towns, the valve may be directly connected with public fire department house or some other suitable place.

The use of both electric and mechanical gongs is strongly recommended. The gong of the latter type can be located on the outside of building or any other desirable place on the premises. When located on the outside all gongs to be protected from the weather.

2. *Alarm Valve.*

To be so located that the passing of water through any of the automatic sources of supply to any of the sprinklers will cause its action.

To accomplish this in some equipments it will be necessary to use two or more alarm valves.

3. *Approval.*

No alarm valve not approved by the underwriters having jurisdiction to be inserted in the sprinkler piping.

Some alarm valves needlessly obstruct the waterway or fail to open when necessary.

4. *Wiring for Electric Alarms.*

To be installed in accordance with the rules of the National Board of Fire Underwriters. (See Signaling Systems.)

VARIABLE PRESSURE ALARM VALVE.

(General Fire Extinguisher Company, Providence, R. I.)

DESCRIPTION.

Figure 30.

A is the shell of the alarm valve.

B is the bronze valve disc.

C is the rubber face of disc B.

D is the bronze seat having a circular groove.

E is the cover for access to valve B.

Figure 31.

F is a ½-inch pipe, connecting the groove in valve seat D, to the drip chamber I.

G is the draw-off valve with pipe for emptying system O.

H is the drip pipe from drip chamber I.

I is a drip chamber to receive and discharge the temporary flow of water which occurs when the valve B is lifted by variable pressure in the supply pipe. The lower figure on page 72 is an enlarged sectional view of the drip chamber I, showing a diaphragm J with valve Z attached, for closing drip pipe H when the drip chamber I is filled by a continuous flow of water, which occurs when the valve B remains open to supply open sprinklers.

K is the pressure gage indicating pressure in sprinkler system O.

L is the pressure gage indicating pressure in supply pipe.

M is the electric circuit closer for sounding alarm.

N is an air vent under the diaphragm of circuit closer.

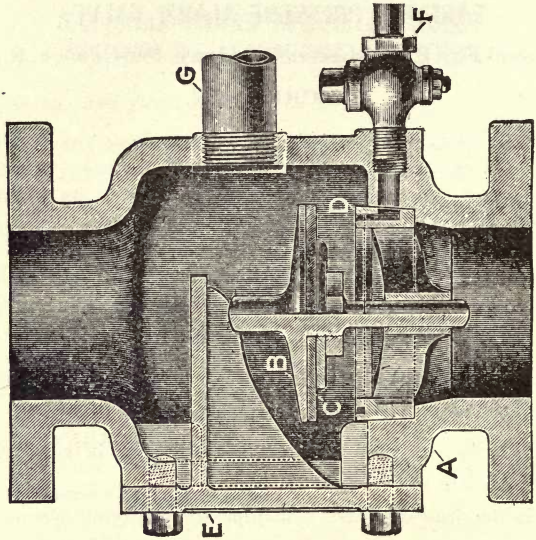
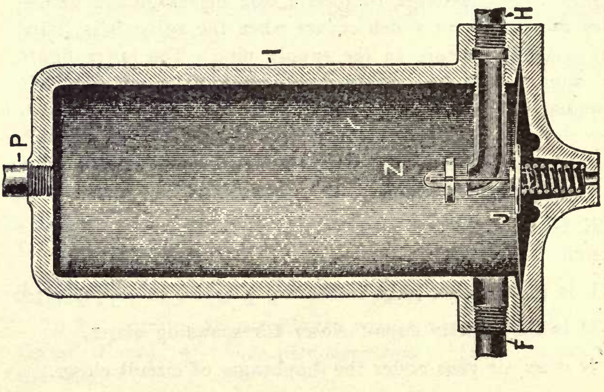


FIG. 30.



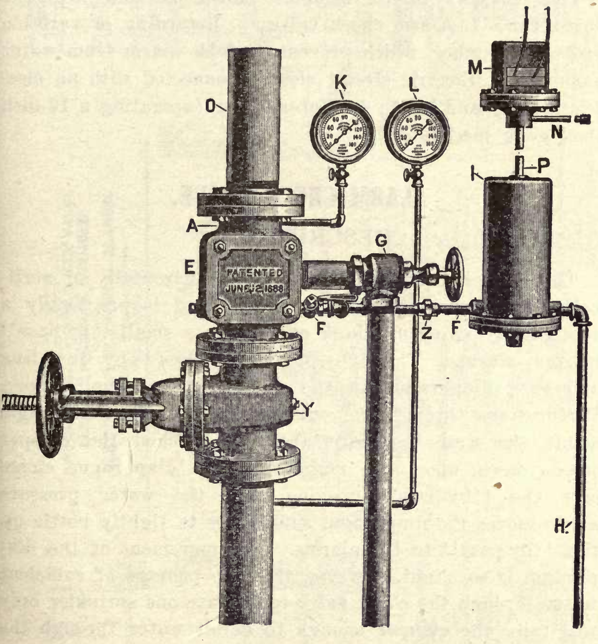


FIG. 31.

"INTERNATIONAL" ALARM VALVE.

(Model C, 1908, Improved.)

(International Sprinkler Company, Philadelphia, Pa.)

This consists in its complete form of four different parts, *viz.:* 1. Alarm check valve; 2. Retarding or variable pressure chamber, which prevents a false alarm from water hammer; 3. Electric circuit closer (connected with an electric battery and bell); 4. Water motor (operating a 16-inch steel gong mechanically).

ALARM CHECK VALVE.

DESCRIPTION.

This goes in the main riser either horizontally or vertically, as circumstances may require, and is practically a straightway swinging check containing a small "by-pass" to the alarm. The "by-pass" is closed by inserting a bronze diaphragm on the under side of the clapper. Perforations through the outside edge of this diaphragm admit the water pressure above it. When the clapper comes down upon the main seat the diaphragm closes over the "by-pass" opening, and the water pressure above moves the diaphragm sufficiently to tightly bottle up this "by-pass" to the alarms. The movement of the diaphragm is so slight, however, that the passage of sufficient water through the check valve to operate one sprinkler only will raise the clapper enough to admit water through the "by-pass" to the alarm system.

VARIABLE PRESSURE CHAMBER.

This is placed between the alarm check and the alarms when the water supply is variable in its pressure and productive of false alarms. It produces a delay of about 15 seconds before permitting the gongs to ring.

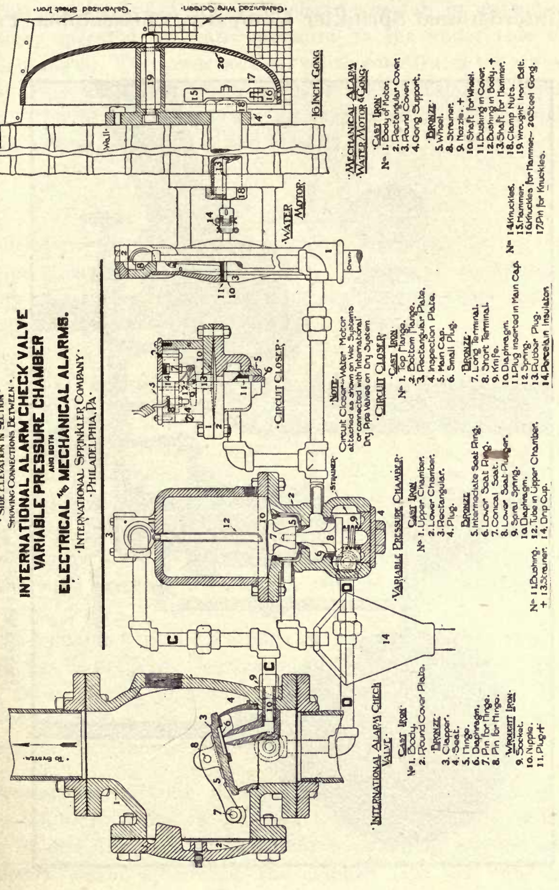
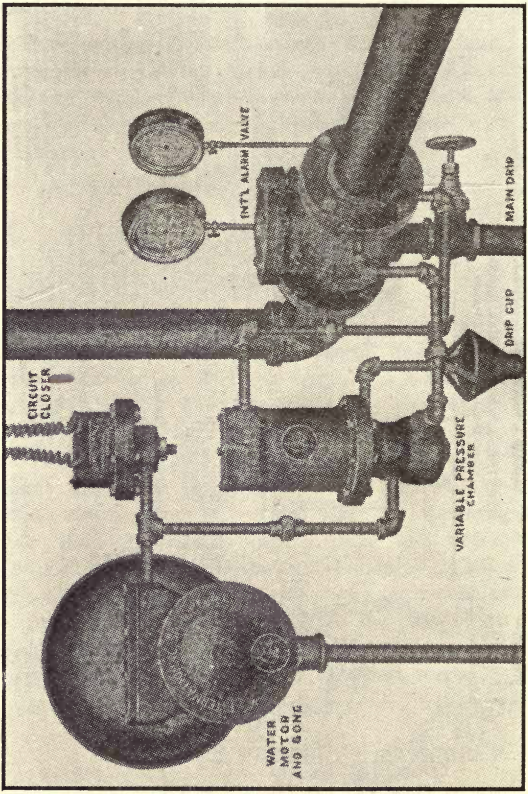

SIDE ELEVATION IN SECTION
SHOWING CONNECTIONS BETWEEN
INTERNATIONAL ALARM CHECK VALVE
VARIABLE PRESSURE CHAMBER
AND BOTH
ELECTRICAL AND MECHANICAL ALARMS.
INTERNATIONAL SPRINKLER COMPANY
PHILADELPHIA, PA.
To System.
Galvanized Sheet Iron.
Galvanized Wire Screen.
Wall.
16 INCH GONG
WATER MOTOR.
CIRCUIT CLOSER.
STRAINER.
Drain
INTERNATIONAL ALARM CHECK VALVE.
CAST IRON.
No 1. Body.
2. Round Cover Plate.
BRONZE.
3. Clapper.
4. Seat.
5. Hinge.
6. Diaphragm.
7. Pin for Hinge.
8. Pin for Hinge.
WROUGHT IRON.
9. Socket.
10. Nipple.
11. Plug.+
VARIABLE PRESSURE CHAMBER.
CAST IRON.
No 1. Upper Chamber.
2. Lower Chamber.
3. Rectangular.
4. Plug.
BRONZE.
5. Intermediate Seat Ring.
6. Lower Seat Ring.
7. Conical Seat.
8. Lower Seat Plunger.
9. Spiral Spring.
10. Diaphragm.
No 11. Bushing. 12. Tube in Upper Chamber.
+ 13. Strainer. 14. Drip Cup.
NOTE.
Circuit Closer-Water Motor attached as shown on Wet Systems or connected with International Dry Pipe Valves on Dry System.
CIRCUIT CLOSER.
CAST IRON.
No 1. Top Flange.
2. Bottom Flange.
3. Rectangular Plate.
4. Inspection Plate.
5. Main Cap.
6. Small Plug.
BRONZE.
7. Long Terminal.
8. Short Terminal.
9. Knife.
10. Diaphragm.
11. Plug inserted in Main Cap.
12. Spring.
13. Rubber Plug.
14. Porcelain Insulator.
MECHANICAL ALARM
WATER MOTOR & GONG.
CAST IRON.
No 1. Body of Motor.
2. Rectangular Cover.
3. Round Cover.
4. Gong Support.
BRONZE.
5. Wheel.
8. Strainer.
9. Nozzle.+
10. Shaft for Wheel.
11. Bushing in Cover.
12. Bushing in Body.+
13. Shaft for Hammer.
18. Clamp Nuts.
19. Wrought Iron Bolt.
No 14. Knuckles.
15. Hammer.
16. Knuckles for Hammer. 20. Steel Gong.
17. Pin for Knuckles.

FIG. 32.

"INTERNATIONAL" ALARM VALVE.

(International Sprinkler Company, Philadelphia, Pa.)



INTERNATIONAL COMPLETE ALARM VALVE.
Mechanical and Electrical.

FIG. 33.

CIRCUIT CLOSER.

This consists of a standard electric switch in an upper section, operated by water pressure on the under side of a diaphragm. The lower section, which constitutes the water intake, has a strainer which can be removed through a main cap. The upper section has an inspection plate, through which access is gained to the electric switch.

WATER MOTOR.

All moving parts are bronze and small in size. In the top section (accessible through a plate) there is a strainer, which may be removed to give access to the water outlet nozzle.

Directions for Care and Maintenance.

Figs. 32 and 33 indicate an "International" alarm valve and all attachments necessary to furnish both electrical and mechanical alarms where variable pressure exists. The photograph illustrates the common practice of placing gauges on either side of the alarm valve and the use of the 2-inch outlet furnished in the alarm valve for the extension of the main drip when the alarm valve is placed at the lowest level.

The variable pressure chamber is designed to prevent any variation in pressure, commonly termed water-hammer, giving false alarms and should always be used where the sprinkler system is connected to city mains, automatic pumps or any supply where the pressure is variable.

Precautions. Alarm Valve.—When attached to air systems the alarm valve should always be located on the water side of the dry pipe valve. Before attaching any of the auxiliary alarm apparatus, the clapper (No. 3) and the hinge (No. 5) should be removed and the system thoroughly cleansed and flushed.

Variable Pressure Chamber.—Always install close to alarm valve and on same level. Never attach to new systems until they are thoroughly cleaned by flushing.

Circuit Closer.—Plug outlet at base when connected as illustrated in Fig. 32. When used without variable pressure chamber and with mechanical alarm place on same level as water motor. Where this arrangement necessitates a run of pipe to a higher level than the alarm valve through an unheated section, provide a 1/16-inch drain outlet for this pipe close to the alarm valve.

INSPECTION.

Should be made only by insurance inspector or person having charge of sprinkler system.

Alarm Check.—Remove main plate and raise or remove clapper to clean seat and have access to all openings.

Variable Pressure Chamber.—Remove top plate to gain access to by-pass (pipe C), strainer and opening into air chamber. Unscrew bottom cap to gain access into lower (main supply) chamber, strainer and valve. Strainer and valve can be pulled down and out for inspection and cleansing.

Circuit Closer.—Remove side plate. The switch, thus exposed, may be raised with a pencil or knife and contact effected. If gong rings the circuit closer is in good condition. See that drip opening underneath is entirely open (when this is used as above instructed).

Water Motor.—Remove top plate to gain access to strainer and jet opening underneath same.

NOTE.—Where outlets come under strainer, the strainer should always be removed and outlet cleaned.

NATIONAL BOARD SPRINKLER RULES.

SECTION H—DRY PIPE SYSTEM AND FITTINGS.

1. *Not Recommended.*

A dry pipe system should be used only when a wet pipe system is impracticable, as in buildings which have no heating facilities.

Dry pipe systems should not be installed where the various parts of a building can be protected from frost by the exercise of reasonable precautions. The use of an approved dry pipe system is, however, far preferable to entirely shutting off the water supply during cold weather.

Air pressure should be maintained on dry pipe systems throughout the year, unless changed by consent of underwriters having jurisdiction.

2. *Drainage.*

Sprinklers to be located in an upright position. All sprinkler pipes and fittings to be so installed that they can be thoroughly drained, and where practicable, all pipes to be arranged to drain at the main drips. Horizontal branch pipes to be pitched not less than ½ inch in 10 feet.

Care should be taken to support the piping in a secure manner, and to see that the sprinklers do not violate the rules for position. (See Section B-3.)

3. *Supply to Enter Below Valve.*

All water supplies to sprinklers should enter the system below the dry pipe valve.

4. *Size of Dry System.*

The number of sprinklers dependent on one dry pipe valve should not exceed 500, preferably not to exceed 300. Where more than 500 sprinklers are necessary in buildings containing two or more floors, the system should preferably be divided horizontally and supplied through two or more dry pipe valves.

5. *Independent Air Filling Connection.*

The connection from the air pump should be made at the dry pipe valve, and on this supply at this point a shut-off valve should be placed and immediately back of it a check valve.

6. *Enclosure of Valve.*

Where exposed to cold the dry pipe valve to be located in an approved underground pit or enclosed in a closet of sufficient size to give 2½ feet free space on all sides of and above and below the valve. Make double walled top, sides and bottom with four (4) inch hollow space. Space may be filled with tan bark, mineral wool, etc., as desired. Heat by steam, lard oil lantern, or gas or electric heater. (Electric heater to be installed in accordance with the National Electrical Code.) A wet pipe sprinkler with a shut-off valve to be placed in the valve closet.

7. *Test Pipe.*

Place a 2-inch pipe directly under every dry pipe valve and provide the same with shut-off valve.

This test pipe provides means of determining whether water is on the system up to the dry pipe valve.

Where the dry pipe valve is enclosed as required in Rule 6 the connection supplying the wet pipe sprinkler may also be used as the supply to the test pipe.

8. *Air Compressor.*

Pump to be of sufficient capacity to increase air pressure not less than 1 pound per 2 minutes pumping (preferably faster).

It is strongly recommended that a steam or electrically driven air pump be used instead of a power pump. The air supply should be taken from outside or from a room having dry air, in order to avoid carrying moisture into the system. The intake should be protected by a screen.

9. *Auxiliary Dry System.*

Where it is necessary to have but twenty-five (25) per cent. or less of the total number of sprinklers on an air system, only such sprinklers should be thus piped; the remainder to be on wet system.

This rule requires small dry pipe systems for show windows, blind attics or other minor portions exposed to freezing.

10. *Flanged Dummy.*

A flanged section of pipe fitted to take the place of dry pipe valve, in case of repairs, to be provided for each style installed.

"ROCKWOOD" DRY PIPE VALVE.

(Worcester Fire Extinguisher Co., Worcester, Mass.)

For illustrations and description of the new "Rockwood" straight way dry pipe valve, see page 382.

"GRINNELL" STRAIGHTWAY DRY PIPE VALVE.

(1908.)

(General Fire Extinguisher Co., Providence, R. I.)

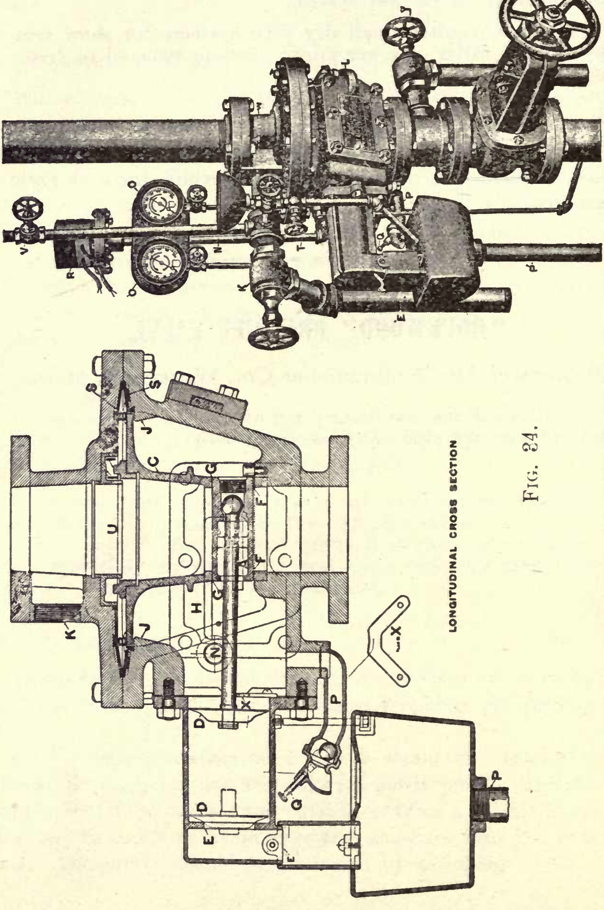
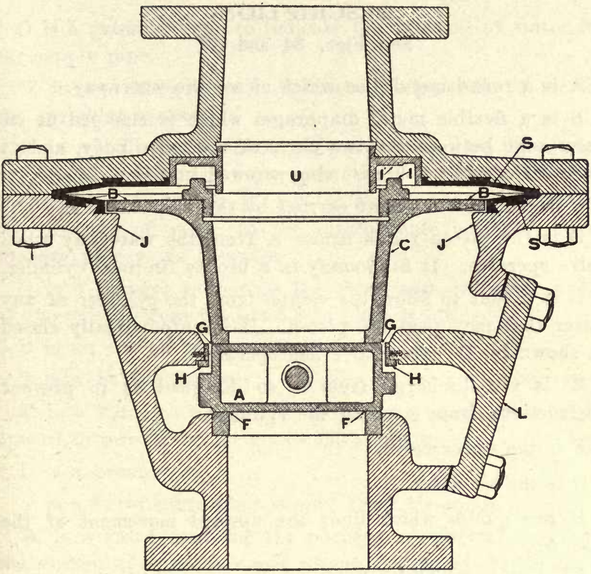
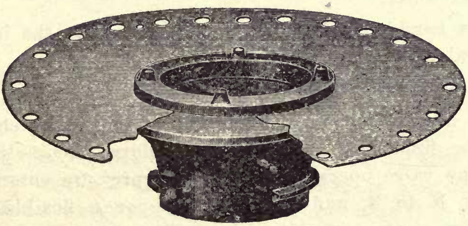


FIG. 24.



Section through Grinnell Valve.



Air Valve Seat "C" and Diaphragm "B."

FIG. 35.

DESCRIPTION.

See Figs. 34 and 35.

A is a round metal disc which closes the waterway.

B is a flexible metal diaphragm which is clamped at its outer edge between the two parts of the valve body, and at its inner edge by a bronze ring screwed into C.

C is the air valve seat carried by the diaphragm B.

D is the piston which draws A from the waterway when valve operates. It fits loosely in a bronze tin-lined cylinder.

E is a vent to allow the escape from the cylinder of any water that may pass the piston. It is automatically closed as shown by D′ after valve has operated.

E′ is the discharge from e, so designed as to prevent obstructions from entering the cylinder.

F is the water valve.

G is the air valve.

H are guides which limit the upward movement of the disc A.

I are stops which by coming into contact with the surface I′, limit the upward movement of C.

J are stops to support C when disc A is withdrawn.

K is the draw-off valve and pipe for emptying the entire system of water.

L is a hand-hole plate which gives access to the interior of the valve.

M is the main gate valve controlling entire system.

N is a pipe which connects the intermediate chamber below the diaphragm B to an electric alarm circuit-closer R. When the valve opens, the full water pressure enters into the pipe N to R, and the pressure upon a flexible metal diaphragm closes a circuit and sounds a continuous electric alarm. The pipe N may also be connected to a water motor alarm and made to sound a continuous mechanical alarm.

O is a pressure gage to indicate the pressure of water in the supply pipe.

O′ is a pressure gage to indicate the pressure of air in the sprinkler system.

P is a ball check valve, so constructed that it allows any slight leakage of water past the valve F to flow out through the drip pipe P′ and is automatically closed by the pressure of water in the intermediate chamber when the dry pipe valve operates.

Q is a plunger to release the check and drain the body of the valve before the hand-hole plate is opened.

R is an electric alarm circuit-closer.

S is a babbit lining.

T is a valve to be kept closed except when valve W is opened to test for water above the air valve.

U is a bronze ring.

V is a valve controlling supply from air-pump.

W is a valve used for the purpose of ascertaining that the system of sprinklers and piping is free of water down to the level of the draw-off pipe.

X is a support for A after it is withdrawn from the waterway.

Y is a test valve to determine amount of water in supply pipe.

OPERATION.

When the air pressure is relieved by the opening of a sprinkler, the disc A is no longer held against the water seat F. The pressure of water then lifts A and C, and entering the intermediate chamber through F, acts on the piston D and disc C. As A is allowed to rise but half the distance which C does, therefore the valve G is forcibly opened, and A is drawn from the waterway by D without chance of sticking to or dragging across either seat, F or G, and a straight, unobstructed passage is left for the water.

D, at the end of its movement, closes the vent E.

The pressure of water in the pipe N sounds an alarm.

DIRECTIONS FOR SETTING.

The valves should never be closed without being thoroughly cleaned, or they may be ruined. Never apply grease, tallow or any oily substance to valve seats F or G.

1st. Shut the main gate valve M in the supply pipe under the valve, and drain the system as described below, then open the check P by pressing on the plunger Q to drain the body of the dry-pipe valve.

2d. Shut the draw-off valve K.

3d. Open the plate L and if A is not out of the waterway, push it out with one hand, holding C up clear of A with the other. Then wipe clean both faces of A, and the seats of F and G.

4th. Hold up C with one hand and push A into position. Let C down easily.

5th. Fill the body of the valve above G with water through the valve W by means of the funnel (valve T being closed). Then close valve W.

6th. Pump up sufficient air-pressure in the sprinkler system to hold the dry-pipe valve closed against the water pressure in the supply pipe.

NOTE.—The difference between the areas of diaphragm B and valve F is such that 1 pound of air pressure on diaphragm B will hold about 6 pounds of water pressure on valve F.

In practice, pressure should be maintained as follows:

NOTE.—In using this table the maximum water pressure to which the system is liable to be subjected should be taken instead of the normal pressure. Fire pumps give at least 100 pounds pressure.

Water Pressure.	Air Pressure. Not Less Than	Air Pressure. Not More Than
50 lbs.	15 lbs.	25 lbs.
75 lbs.	20 lbs.	30 lbs.
100 lbs.	25 lbs.	35 lbs.
150 lbs.	35 lbs.	50 lbs.

7th. Open main gate valve M wide, and see if the valves F and G are tight. If no leak is found, bolt on the plate L so that the joint will be water-tight. If either F or G leaks it will be on account of dirt on the seat. In this case shut the main gate valve M, and let the air pressure off through the valve K. Clean the surfaces of the disc A and the valve seats F and G and reset the valve.

The above described method of closing the valve prevents any sediment being lodged on the valve seats, and it will be seen that one of the special objects of the peculiar construction of this valve is to thus give opportunity to perfectly clean the valves and seats before subjecting them to pressure.

Water must not be allowed to stand above the draw-off valve W, where it might freeze or exert pressure on the air valve.

INSPECTION.

1st. Open valves T and W to see that the system of sprinklers and piping is free of water down to this level. If any water appears, draw it off, and then tightly close valves T and W.

2d. Open the hand-hole plate L occasionally (say, twice a year) and see that the water valve F and the air valve G are tight; also that the intermediate chamber is clear and free from deposits or other obstructions. This is accomplished by simply looking in at the hand-hole. Then shut and bolt on plate L.

3d. Test automatic alarm.

4th. After making the above examination there is nothing more for an inspector to do; and it follows that, as far as the Grinnell valve is concerned, the system is in perfect working order.

TO DRAIN THE SYSTEM.

Whenever a dry-pipe system has been filled with water, the following directions for emptying the system should be observed:

1st. Close main gate valve M in supply pipe under dry-pipe valve.

2d. Open draw-off valve K, closing it when water has ceased to run.

3d. Open drip valves and vents throughout the system, closing them when water has ceased to run.

4th. Pump a few pounds of air pressure on the system.

5th. Open drip valves and vents separately (drips to be opened first), to force water from low points of the system.

6th. Set dry-pipe valve and pump up air pressure, as above described.

CAUTION.—As water from condensation may settle at the low points of the system, it will be prudent to occasionally open valve W and other drips throughout the system and if water appears draw it off, closing the valves tightly as soon as air appears.

"INTERNATIONAL" DRY PIPE VALVE.

(Model No. 4, 1908.)

(International Sprinkler Company, Philadelphia, Pa.)

DESCRIPTION.

The valve consists of a main body, divided into an upper ("air chamber"), an intermediate chamber (under atmospheric pressure when the valve is "set"), and a third ("water intake") chamber normally closed by a swinging check. This latter check also serves, however, a second function, *viz.*, to close the atmospheric opening through the intermediate chamber by its reverse side when the valve opens and water is admitted to the sprinkler system. The hinge of this water check is of peculiar form, consisting of a long, slotted, protruding stem, which swings on a fork centrally attached thereto. The outside end of this stem is engaged by a set screw, which is adjusted through the upper end of a hook, loosely swinging on knife-edged ears. The lower end of this hook is caught on a weight swinging loosely on a pin. This weight, in turn, engages with a tumbler loosely swinging on a knife-edge pin. This tumbler is held by the air clapper by means of a vertical strut passing loosely through the slot in the fork, the movement of this strut being limited by a loose pin connecting it with the fork. The entire mechanism, therefore, practically consists of three loosely swinging levers connecting a standard air check with a standard water check. All the working mechanism lies entirely out of the water ways. The entire area of contact between the working parts hardly exceeds a square inch. All these contacts separate with an angular movement, hence no corrosive action could possibly prevent the valve from opening. The air and water valves are of equal area, and make metal to metal contacts.

In the "International" dry valve the air and water clappers are of equal area, and the control of the water supply by relatively lower air pressure is secured by mechanical differentiation. The air clapper is the "tripping" device.

It opens by the combined action of water pressure and the use of a weight; the weight, regardless of water pressure, causing opening when the air pressure is reduced to 9 pounds per square inch. This weight would, therefore, lift a column of water in the air system more than 20 feet in height, should it accidentally be present. The influence of the water supply on this device is limited (by the leverages employed) to 6 pounds per square inch against the air clapper. When the adjusting screw is set tight enough to hold any available water pressure, the valve still opens at not more than 15 pounds of air pressure.

Directions for Care and Maintenance.

To Set Valve "Dry."

1. Close all supply valves. Open all drip valves, and drain the system thoroughly, opening air cocks or removing plugs at end of line on each floor.

2. Open cover plate (No. 4) on side of valve. Wipe carefully face of clapper for air seat (No. 13), air seat ring (No. 24), re-set clapper (No. 13) on seat (No. 24), wipe both faces of water clapper (No. 12), water seat ring (No. 14) and outer seat ring (No. 20). Be sure that no grit or dirt of any kind remains to prevent clappers from seating properly. Replace cover plate (No. 4).

3. By using primer (see page 387) be sure there is at least 12 inches of water above the air clapper (No. 13).

4. Close all drips and pump air pressure up to 30 pounds.

5. Open each drip valve on the system, and allow the air pressure to blow out any water remaining in the system.

6. When the system is entirely drained of water, prime as outlined above, then pump 30 pounds of air pressure into system. This pressure is sufficient to safely hold any available water pressure. Never permit air pressure to fall below 25 pounds, for below that pressure there is danger of the valve tripping. Never pump air pressure higher than 30 pounds, for while excess pressure is being exhausted water is delayed from reaching fire.

7. Loosen the adjusting screw (No. 23) so that inside end does not project through bearing. Bring water clapper (No. 12) into position. Raise ball weight (No. 6) with left hand, bringing hook (No. 8) and tumbler (No. 9) with right hand into position. With ball weight still held up high and adjusting screw still loose, bring strut (No. 10) with right hand into position between air clapper (No. 13) and tumbler (No. 9). Screw up adjusting screw (No. 23) with moderate strain, using one hand on a 9- to 12-inch wrench. See that air pressure is fully 30 pounds and air seat properly primed. Examine ball drip for leakage at air seat. If tight, then turn water on slowly by opening supply gate valve. Should any leak from water seat show through ball drip, tighten adjusting screw (No. 23) until leak ceases.

8. When both air and water seats are tight, which is indicated by the absence of water through ball drip, close and lock covers. The system is then ready for service.

NOTE.—It is necessary to open all drip valves occasionally (during a warm day in winter) to allow any water which may have condensed through pumping warm air in cold pipes, to escape, otherwise these low places at the drip might freeze, bursting the pipes and thus crippling the entire air system.

Inspection.

1. Open ½-inch test valve (soft-seated globe valve) and see that system is free from water to level of valve.

2. Test-cock for water should be placed on end of main drip port for test of water above air clapper. Air being found at this point, valve should be primed with water up to air test valve by use of primer.

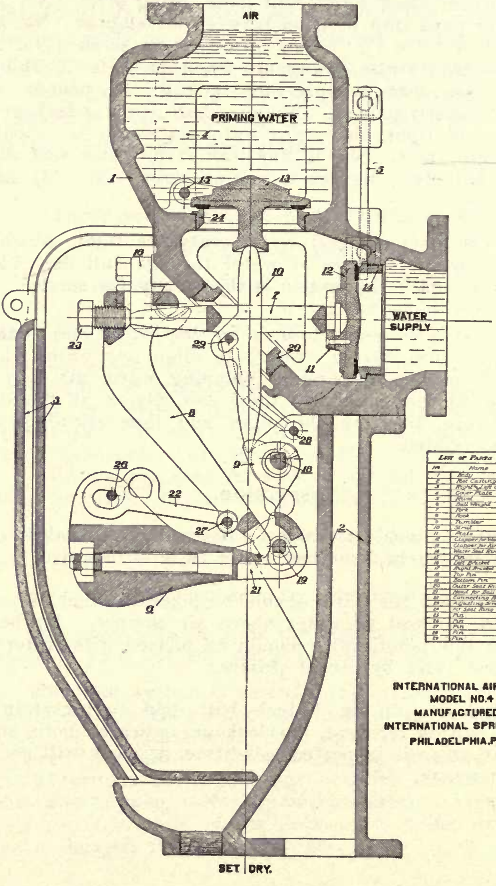
3. Push in pin on ½-inch ball drip to ascertain if ½-inch ball is off seat, no leakage indicates both seats are tight, valve is in perfect condition, as parts will not go together wrong.

"INTERNATIONAL" DRY PIPE VALVE.

Model No. 4.

(International Sprinkler Co., Philadelphia, Pa.)

DESCRIPTION OF VALVE AND PARTS.



LIST OF PARTS	
No	Name
1	Body
2	Post Casting
3	Right & Left Cover
4	Cover Plate
5	Rivet
6	Ball Weight
7	Fork
8	Hook
9	Tumbler
10	Strut
11	Plate
12	Clapper for Water Seal
13	Clapper for Air Seal
14	Water Seal Ring
15	Pin
16	Left Bracket
17	Right Bracket
18	Top Pin
19	Bottom Pin
20	Outer Seat Ring
21	Head for Ball Weight
22	Connecting Rod
23	Adjusting Screw
24	Air Seat Ring
25	Pin
26	Pin
27	Pin
28	Pin
29	Pin

INTERNATIONAL AIR VALVE
MODEL NO.4
MANUFACTURED BY
INTERNATIONAL SPRINKLER CO
PHILADELPHIA, PENNA

No. 1. Body.
No. 2. Foot casting.
No. 3. Right and left cover.
No. 4. Cover plate.
No. 5. Rivet.
No. 6. Ball weight.
No. 7. Fork.
No. 8. Hook.
No. 9. Tumbler.
No. 10. Strut.
No. 11. Plate.
No. 12. Clapper for water seat.
No. 13. Clapper for air seat.
No. 14. Water seat ring.
No. 15. Pin.
No. 16. Left bracket.
No. 17. Right bracket.
No. 18. Top pin.
No. 19. Bottom pin.
No. 20. Outer seat ring.
No. 21. Head for ball weight.
No. 22. Connecting rod.
No. 23. Adjusting screw.
No. 24. Air seat ring.
No. 25-29. Pins.

NOTE.—For exterior view of "International" Dry Pipe Valve set "dry," see page 387.

"MANUFACTURERS" DRY PIPE VALVE.

(Manufacturers Automatic Sprinkler Co., N. Y. City.)

DESCRIPTION OF VALVE AND PARTS.

(See Figs. 38 and 38A).

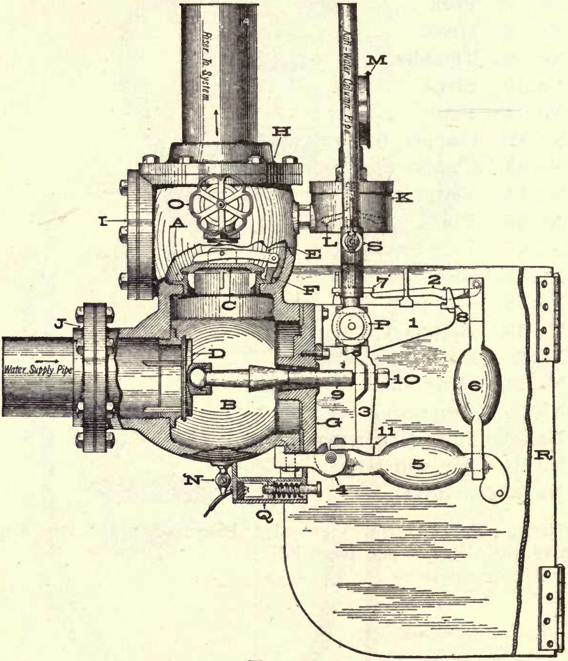


FIG. 38.

No. 1. Lever support.

No. 2. Flat horizontal lever.

No. 3. Yoke lever.

No. 4. Lever hinge.

No. 5. Horizontal weight lever.

No. 6. Upright weight lever.

No. 7. Link lever.

No. 8. Fulcrum.

No. 9. Stem to main water valve.

No. 10. Set screw.

No. 11. Lower link.

A and B. Upper and lower chambers of valve body.

C. Swing check valve. To divide upper and lower chambers.

D. Main water valve.

E and F. Arm and support. To swing check valve "C."

G. Face flange. To main water valve "D."

H. Outlet flange. To sprinkler system.

I. Face flange. To swing check valve "C."

J. Inlet flange. To water supply pipe.

K. Air cup. Controlling leverage system.

L. Valve and steam.

M. Gage.

N. Drain cock. To lower chamber "B."

O. Main drain valve. To "riser."

P. Drain valve. To "anti-water column."

Q. Alarm closing device.

R. Valve shield.

S. Test cock. To "anti-water column."

"MANUFACTURERS" DRY PIPE VALVE.

(Manufacturers Automatic Sprinkler Co., New York, N. Y.)

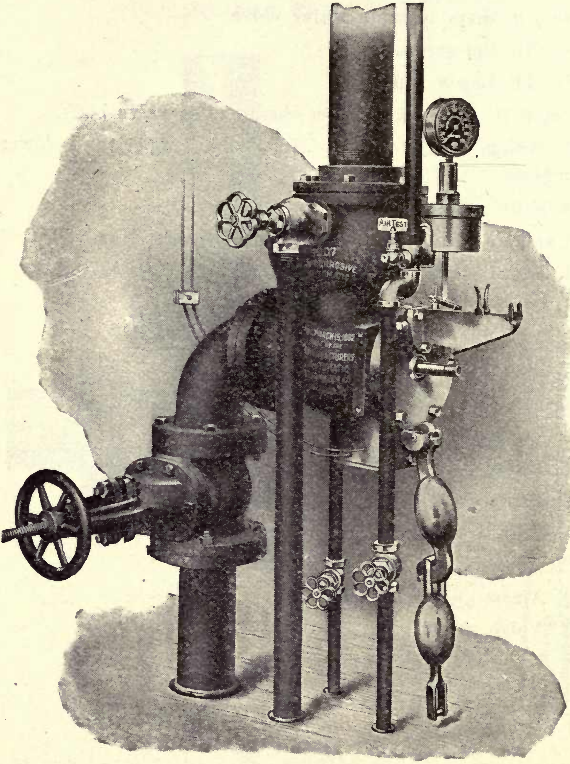


FIG. 38A.

To Drain a Dry Pipe System Which Has Been Operated as Wet Pipe During the Summer Months.

First. Close the controlling gate valve in water supply pipe.

Second. Open all drain valves throughout the system and close them when water stops flowing. Care should be taken that system is properly drained and that piping is not allowed to sag and form water pockets, which would freeze under the dry pipe system.

Third. Pump a few pounds of air into system, then again open all drain valves which will have a tendency to drive water from low points in the piping.

Fourth. Close all drain valves and set dry pipe valve (see Instructions).

Instructions for Setting "Manufacturers" Dry Pipe Valve.

First. Close the controlling gate valve in water supply pipe and open all drain valves in sprinkler system, and leave open until all water is drained from the pipes, then close all drain valves throughout the system.

Second. (1) Lift the stem ("L"), which has attached valve, in air cup ("K"), and with the finger remove from valve seat any foreign substance. (2) Place horizontal lever No. 2 in position, the end resting under link lever No. 7, on which rests stem ("L"). (3) Lower stem ("L"), allowing valve to reseat itself. (4) Start air pump and when gage ("M") registers 2 pounds pressure open drain valve ("P") to blow out any dirt. (5) Close drain valve ("P").

Third. Pump necessary air pressure (30 to 40 pounds) into the system.

Fourth. Lift upright weight lever No. 6 to position, taking

its bearing on end of lever No. 2, placing lower end of yoke lever No. 3 in link No. 11, and bringing upper end in position under shoulder of lever support No. 1.

Fifth. Place main water valve ("D") to its seat by means of stem No. 9.

Sixth. Place link No. 11 on shoulder of horizontal weight lever No. 5.

Seventh. (1) Tighten set screw No. 10 with fingers sufficient to hold yoke lever No. 3 in place. (2) Close drain cock ("N"). (3) Open controlling gate valve in water supply pipe about one-third. (4) With a wrench slowly tighten set screw No. 10 until main water valve ("D") stops leaking. Care should be taken not to place more tension on set screw No. 10 than is necessary to prevent the main water valve ("D") from leaking at pressure obtained.

Eighth. Open drain cock ("N") and empty the lower chamber ("B"). The dry pipe valve is now set complete and ready for operation.

Ninth. Open wide the controlling gate valve in water supply pipe and strap the same open.

Tenth. Close valve shield ("R").

Eleventh. Test alarm circuit to ascertain if in order by pressing in on stem of alarm closing device ("Q").

To Test "Manufacturers" Dry Pipe System When Dry Pipe Valve is Set.

First. Close the controlling gate valve in water supply pipe.

Second. Open drain valve (P) to drain off air pressure when dry pipe valve will trip and operate as in case of a fire, but will not allow water into system.

Third. Close drain valve (P).

Fourth. Reset valve as per instructions (two to eleven).

SOURCE OF WATER SUPPLY FOR SPRINKLER SYSTEMS.

For an efficient sprinkler system it is absolutely necessary that the source of water supply should be both certain and adequate and to insure certainty there should be at least two sources of supply, which should be used exclusively for the sprinkler system.

The source of water supplies are usually public or private reservoir, public water mains from two streets, air pressure tanks, gravity tanks, fire pumps, and city steamer or fire engine of the Public Fire Department.

In arranging a sprinkler system it should be the aim to make the first sprinklers that are opened as effective as possible, which depends very largely on the pressure under which they open. A light pressure may result in the failure of the first sprinklers that open to completely arrest the fire, and consequently cause the opening of a large number of heads with comparatively serious results.

In the typical sprinkler systems of the large cities there are generally four sources of water supply to the main risers of the system, as shown in Fig. 39, and in the Perspective View Showing the Application of The Automatic Sprinklers in a Modern Factory, page 257.

They may be divided into two classes, the Automatic Supplies, consisting of the pressure tank, gravity tank, automatic pump, and occasionally the city water mains, and the Manual or Auxiliary Supply, The Public Fire Department or the City Steamer.

Naturally, the automatic supply producing the highest water pressure would be considered the primary source of supply, whether city water pressure, pressure tank, gravity tank or automatic pump.

In order to illustrate the operation of typical system we will assume that the highest pressure before a sprinkler releases, is produced by the pressure tank.

The main pipe leading from each source of supply contains a check valve. These valves are installed for the

purpose of preventing the water from flowing in any direction other than that of the open sprinkler when the supply from one or more sources has become exhausted.

These valves are indicated on the diagram by crosses and are lettered A, B, C, D and E.

Primary Source of Water Supply.

The primary source of water supply is the PRESSURE TANK. This can readily be seen by examining the diagram.

With 75 pounds pressure on the pressure tank, which is the usual pressure per square inch required to be maintained, check valve B would close unless the gravity tank was placed high enough to produce a pressure greater than that of the pressure tank. This would mean that the gravity tank would have to be elevated to a height of about 175 feet above the pressure tank, which is impracticable.

As the fire pump is not running continuously, the check valve D would normally remain closed due to excess pressure from the primary (pressure tank) supply. And as the fourth source of supply or the steamer is not maintained at all times, the check valve E would be closed. We then have check valve A and C open, with check valve B, D and E closed, making the pressure tank the primary source of supply.

Second Source of Water Supply.

The second source of water supply is the GRAVITY TANK.

As I have stated above, check valves D and E are closed. When the source of water supply is becoming exhausted in the pressure tank, the pressure will drop, and when this pressure falls below that due to the height of the gravity tank above the pressure tank, check valve B will open and check valve A will close, making the gravity tank the source of supply.

DIAGRAM SHOWING THE FOUR SOURCES OF WATER SUPPLY TO A SPRINKLER SYSTEM.

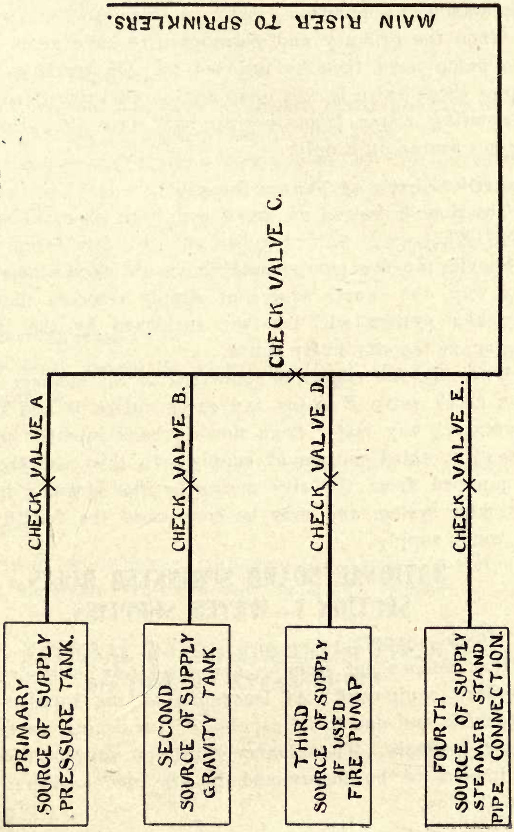


FIG. 39.

Third Source of Water Supply.

The third source of water supply is the FIRE PUMP, that is, if the building in which the sprinkler system is located contains such a pump.

When the primary and second source have given out the fire pump must then be resorted to. On starting the fire pump check valve D will open and check valve C will close, preventing water from flowing back into the primary or second source of supply.

Fourth Source of Water Supply.

The fourth source of water supply is the CITY FIRE ENGINE.

Should the fire pump break down or become disabled in any way, the fourth source of supply resorted to for the sprinkler system will be that furnished by the city fire engine, or the city water mains.

When the fire engine is connected to the steamer connection check valve E opens and check valves D and C close, preventing any water from flowing back into the primary, second or third sources of supply. In this case the water is pumped from the city mains by the steamer into the sprinkler system and may be considered the fourth source of water supply.

NATIONAL BOARD SPRINKLER RULES.
SECTION I—WATER SUPPLIES.

1. *Double Supply.*

Two independent supplies are absolutely necessary for a standard equipment. At least one of the supplies to be automatic and one to be capable of furnishing water under heavy pressure. The choice of water supplies for each equipment to be determined by the underwriters having jurisdiction.

2. *Size of Connection.*

Connection from water supply or main pipe system to sprinkler riser to be equal to or larger in size than the riser.

NATIONAL BOARD SPRINKLER RULES.
SECTION J—PUBLIC WATER WORKS SYSTEMS.

(Rules also applicable to private reservoir and stand pipe systems.)

1. *Pressure Required.*

Should give not less than 25 pounds static pressure at all hours of the day at highest line of sprinklers.

Where the normal static pressure complies with the above, the supply to be also satisfactory to the underwriters having jurisdiction, in its ability to maintain 10 pounds pressure at highest sprinklers, with the water flowing through the number of sprinklers judged liable to be opened by fire at any one time.

2. *Size of Mains.*

Street main should be of ample size, in no case smaller than 6 inches.

3. *Dead Ends.*

If possible, avoid a dead end in street main by arranging main to be fed at both ends.

4. *Meter.*

No water supply for sprinklers to pass through a meter or pressure-regulating valve, except by special consent.

NATIONAL BOARD SPRINKLER RULES.
SECTION K—STEAM PUMP.

1. *Type.*

To be in accordance with the National Standard specifications.

2. *Capacity.*

To be determined by underwriters having jurisdiction in each instance, but never less than 500 gallons rated capacity per minute.

3. *Location.*

To be so located on the premises as to be free from damage by fire or other cause. Pump room should be readily accessible and provide easy and safe egress for attendant.

A clean and well-floored room with a tight roof should be provided for a fire pump. No room is acceptable where the conditions prevent or discourage the engineer from keeping the pump in good condition.

4. *Suction and Water Supply.*

To take water from an approved source having an available supply specified by the underwriters having jurisdiction, but never less than 60 minutes' supply while the pump is delivering its rated capacity.

The capacity specified is the minimum acceptable. A larger supply should be provided in large plants and where the continued use of hose, open sprinklers, or both, may be necessary

5. *Intake Well.*

When a pump takes suction from a river, lake, or other large body of water, an effectively screened intake well (brick or concrete preferred) should be provided. The well to be deep enough to be free from ice or accumulation of dirt.

6. *Cistern.*

When a pump takes suction from a cistern, reliable means for keeping the cistern full should be provided, particularly where the water can be used for other purposes. Where water from public service mains is available, a filling connection not smaller than 2 inches and equipped with a ball and cock valve should be provided. Where possible, the cistern should be constructed so as to supply the water to the pump under head for at least 10 minutes. A sump should be provided in the bottom so that all of the water will be available. See Rule 4 for capacity.

7. *Public Mains.*

When a pump takes suction from public service mains, the reliability of the supply should be ascertained beyond any reasonable question of doubt.

If the plant is remote from the public pumping station and supplied through a long main having a dead end, this source of supply may be entirely unreliable, even though the mains are reasonably large and the normal pressures comparatively high. The possible interruption of the supply by city fire engines, and by other means not under the control of the owner of the plant, should be taken into consideration in determining this source of water supply.

8. *Lift.*

Pump to be so located in respect to its water supply that at no time will it have a lift of over 15 feet during 60 minutes' discharge at rated capacity.

When a pump takes water under head, there should be an approved indicator gate valve in the suction pipe, located at the pump.

9. *Suction Pipe.*

Suction pipe to be as short and direct as possible, to be free from air pockets and leaks and so located that water in same will not freeze during the most extreme weather. To be provided with a strainer so located with reference to the bottom of cistern, or intake, that it will be free from possible accumulation of dirt and afford free entrance of water when the pump is running at full rated capacity. A foot valve is not advised in ordinary cases.

In extreme cases, where the lift is unavoidably in excess of 15 feet and where the suction pipe is necessarily long, a foot valve may be used. The foot valve to comply with the above requirement regarding the location of the screen.

If supply is from a cistern the end of the suction pipe should be located in a sump, so that all of the water can be drawn from the cistern

10. *Steam Connections.*

Pump to be supplied through independent connection from boilers, so installed as to be free from pockets or traps and so located as not to be subject to injury in case of fire or other accident; to be fitted with drip pipe and steam trap at the pump, so connected that the closed throttle valve will not prevent the operation of the steam trap. When possible, the steam connection from the header at boilers should be taken from the end opposite to that from which the supply for large engine is taken. The steam connection should be pitched so that as much condensation as possible will drain back to the boilers.

11. *Steam Valves.*

Where there is more than one boiler, the arrangement of pipes and valves to be such that each boiler may be "cut out" without interrupting steam supply to pump from the other boilers. Where there are several fire pumps, each should be arranged to be "cut out" without affecting the others.

Valves to be located in boiler house so that all steam supply to other buildings may be cut off from them at time of fire and reserved for pump.

12. *Exhaust Pipe.*

Each pump to be provided with an independent exhaust pipe, free from liability to back pressure and equipped with an open drain pipe at lowest point.

13. *Steam Pressures.*

Steam pressure of not less than 50 pounds to be maintained at the pump at all times.

14. *Boilers.*

Provision to be made for sufficient steam power to run pump to full rated capacity; not less than 40 H. P. for each 250 gallons rated capacity of pump. Boilers to be supplied with ample water supply not liable to be crippled in case of fire. Where forced draught is necessary, provision should be made for safe, independent control of the same.

15. *Boiler House.*

Any boiler house on which pump depends for steam supply should be of brick or stone, detached, or cut off from main buildings by standard fire doors.

16. *Priming Tank.*

Where pump does not take water under head, it should be primed from a water tank, or its equivalent, having a capacity not less than one-half the full capacity of the pump for one minute. The tank to be safely located and used exclusively for this purpose.

17. *Automatic Regulator.*

If an automatic regulator is placed in steam connection to pump, it should be on a by-pass with a shut-off valve on each side of same. These valves to be in addition to the valve for operating the pump independently of the regulator. The connection from the regulator to the water end of the pump to be of ½-inch brass pipe.

Regulator to be installed in accordance with the Rules of the National Board of Fire Underwriters.

18. *Recording Gage.*

Where a steam pump is the primary supply an approved automatic recording gage, when required, may be applied to record the steam pressure in pump steam chest or water pressure in pump discharge.

Under the above arrangement the gage will indicate when the steam to the pump has been shut off. The gage should be placed on the wall near the pump, in proper box or cabinet, which should contain blank dials, ink, etc., together with the file of used dials.

19. *Hose Connections.*

When hose connections at pump are not conveniently located, pump may be fitted with a discharge pipe leading to a convenient location for attachment of the hose valves. A shut-off gate may be required in this pipe. This discharge pipe to be taken out back of the gate and check valve in the main discharge pipe.

20. *Test.*

Fire pump to be operated at least once a week.

THE NATIONAL STANDARD STEAM PUMP.

Key to Illustration.

1. Main steam pipe direct from boilers independent of all other pipes. Valves at boilers so arranged that steam can be shut off from factory supplies and reserved for fire pump.

2. Main throttle valve.

3. Automatic regulator placed on a "by-pass" around main throttle. For ordinary conditions it does not need to be full size of steam inlet, 1½-inch or 2 inches is sufficient for a 1,000-gallon pump.

4. Controlling valves for automatic regulator of globe pattern to be kept wide open.

5. Sight feed lubricator.

6. Steam gage attached directly to steam chest.

7. Hand oil pump. Glass body with one pint capacity.

8. Hand wheels operating cushion valves for regulating stroke of pump.

9. Waste pipe from relief valve. This should be carried outside pump house, and if pump draughts from cistern or other limited supply of water, waste pipe should discharge into this supply.

10. Open cone on waste pipe.

11. Relief valve, spring pattern.

12. Suction air chamber.

13. Six or 8-inch pipe extending from pump discharge through wall of pump house. The hose valves each with its independent gate to be attached to this, leaving a hole in wall, covered to prevent freezing. This method does away with short bends in hose.

14. Air chamber.

15. Name plate.

16. Duplex spring water-pressure gage.

17. Horizontal straightway check-valve.

18. Outside screw and yoke or other approved indicator gate-valve.

19. Priming tank.

20. Priming valve, pipe from tank to be not less than $2\frac{1}{2}$ inches diameter.

21. Priming checks and reliefs.

22. Lever handle air cocks, relieving the air cushion in force chamber of the pump.

23. Lever handle drip cocks for draining.

24. Stroke gage with marked lines showing full stroke of pump. There shall be a fixed index on piston rod so that pump stroke can be accurately measured.

25. Drip cocks and open cups.

26. Steam trap.

27. Pocket for strainer, easily removed and cleaned.

28. Brass tube, $\frac{1}{2}$ inch in diameter, being water pressure connection to automatic regulator.

29. Brass globe valves.

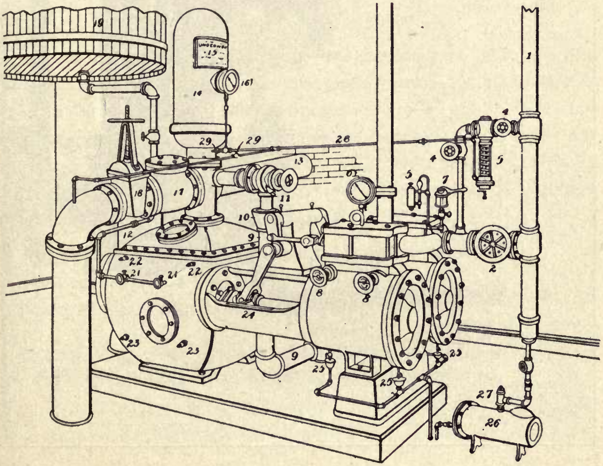


FIG. 40—NATIONAL STANDARD STEAM FIRE PUMP.

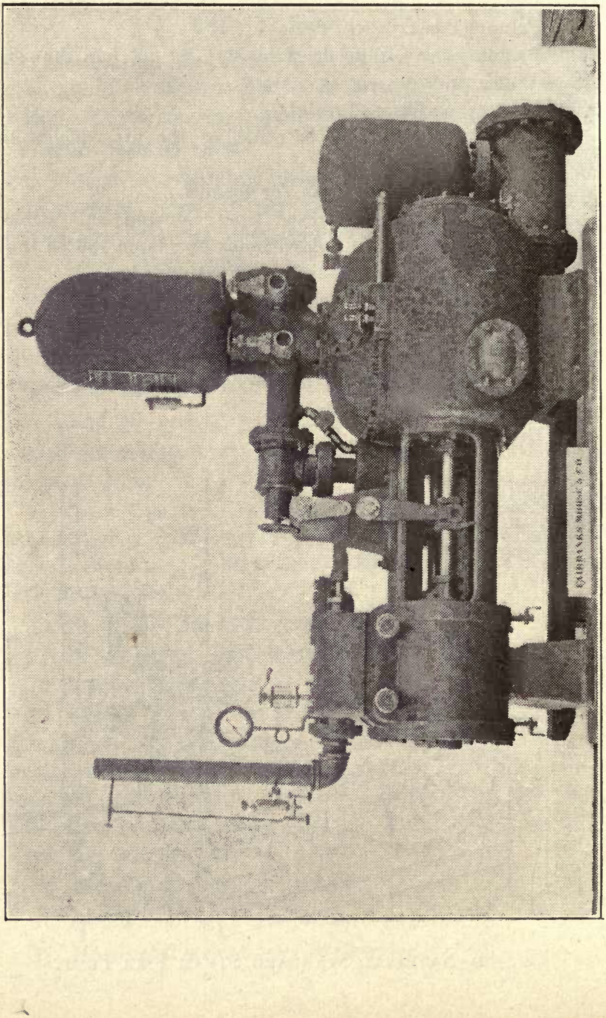


FIG. 41—UNDERWRITERS STEAM FIRE PUMP.

SPECIFICATIONS

OF THE

NATIONAL BOARD OF FIRE UNDERWRITERS

FOR THE MANUFACTURE OF

STEAM FIRE PUMPS

AS RECOMMENDED BY THE

NATIONAL FIRE PROTECTION ASSOCIATION.

EDITION OF 1904.

UNIFORM REQUIREMENTS.

The following specifications for the manufacture of Steam Fire Pumps, developed from those originally drawn by Mr. John R. Freeman, are now used throughout the whole country, having been agreed upon in joint conference by representatives of the different organizations interested in this class of work. They will be known as "The National Standard," and have been up to this time adopted by the following associations:

Associated Factory Mutual Fire Insurance Companies.
National Board of Fire Underwriters.
National Fire Protection Association.

NOTE.—Pages 111 to 165 are a reprint of the pamphlet on Steam Fire Pumps of the National Board of Fire Underwriters.

THE NATIONAL STANDARD PUMP.

This pump is merely a pump of the well-known "duplex" type, built in a very substantial manner, and with certain improvements suggested by the experience of inspectors with Fire Pumps.

The principal points of difference between the National Standard Pump and the ordinary commercial pump are :

1st. Its steam ports and water passages and air chamber are made much larger than in common trade pumps, so that a larger volume of water can be delivered in an emergency without water hammer.

2d. It is "rust proofed" that it may start instantly after disuse, by making its piston rods and valve rods of Tobin Bronze, instead of steel; its water pistons, stuffing boxes and rock-shaft bearings of brass, instead of cast-iron. Its valve-levers are made of steel or wrought-iron forgings, or of steel castings.

3d. The following necessary attachments are all included in the price of the "National Standard Pump," viz.:—a vacuum chamber, two pressure gages, a relief valve, a set of brass priming pipes, 2 to 6 hose valves, a stroke gage, a capacity plate, an oil pump, a sight feed lubricator and a cast-iron relief-valve discharge-cone.

By reason of the larger ports, passageways and pipes, its larger number of valves, and the added attachments, and general superior construction a "National Standard" pump costs more than a common trade fire pump, but the cost per gallon which these pumps can **deliver in an emergency** by reason of their large passageways, etc., is no greater than for the old style of fire pump and is well worth this extra cost.

Finally it should be remembered that these specifications cover only the outlines of the design, and that all pumps built under them are not of equal merit, for certain of the pump factories possess a broader experience and better shop facilities than others, and that the responsibility for first-class workmanship and strength of materials rests on the pump manufacturers, and not on the insurance companies.

We advise that all contracts call for strict conformity to the National Standard Steam Fire Pump specifications of the National Board of Fire Underwriters.

NATIONAL STANDARD SPECIFICATIONS FOR THE MANUFACTURE OF STEAM FIRE PUMPS.

1. *Workmanship.*

a. The general character and accuracy of foundry and machine work must throughout equal that of the best steam-engine practice of the times, as illustrated in commercial engines of similar horse-power.

This refers to strength of details, accuracy of foundry work, accuracy of alignment, accuracy of fits, quality of steam joints and flanges, construction of steam pistons and slide-valves, etc., and does not apply particularly to exterior finish.

2. *Duplex Only.*

a. Only "Standard Duplex pumps" are acceptable.

So-called "Duplex" pumps, consisting of a pair of pumps with "steam-thrown valves" actuated by supplemental pistons, are not acceptable.

Experience shows that duplex pumps are more certain of starting after long disuse. The whole power of the main cylinder is available for moving a corroded valve or valve rod, whereas on a single pump with a "*steam-thrown*" valve no such surplus of power is available.

Further, the direct acting duplex has the great advantage over a fly-wheel pump of not suffering breakage if water gets into steam cylinder.

3. *Sizes of Pumps.*

a. Only the four different sizes given on the next page will be recognized for "National Standard" pumps.

The multiplicity of odd sizes of "Trade Pumps" is confusing, and different makers have, in the past, estimated the capacity in gallons according to different arbitrary standards.

NATIONAL STANDARD PUMP SIZES.

Pump Sizes.			Ratio of Piston Areas.	Capacity at 100-Lbs., at Pump.			*Boiler Power Required.		Full Speed.	
Steam.	Water.	Stroke.	About	Number of 1⅛-In. Streams.	Nominal Gallons Per Minute.	Actual Gals. per Min. as per Art. 4.	Horse Power.	Steam Pressure at Pump, Lbs.	Revolutions Per Minute.	Piston Travel Feet Per Minute.
14 14	x 7 x 7¼	x 12 x 12	4 to 1	**Two**	**500**	483 520	100	40	70	140
16	x 9	x 12	3 to 1	**Three**	**750**	806	115	45	70	140
18 18½	x 20 x 10¼	x 12 x 12	3 to 1	**Four**	**1000**	999 1050	150	45	70	140
20	x 12	x 16	2¾ to 1	**Six**	**1500**	1655	200	50	60	160

b. The above sizes of steam and water cylinders and length of stroke have given general satisfaction and will now be considered as standard.

---

*This boiler power is required for continuous running at full speed and pressure. It is, however, often best to put in a larger pump than the existing boilers could drive at full capacity, as a *small boiler will drive a* 750-*gallon pump at the* 500-*gallon speed with very nearly as good economy as it can drive a* 500-*gallon pump at full speed.* The pump then does not have to be changed when the plant is enlarged and the boiler power increased.

A steam piston relatively larger than necessary is a source of weakness. It takes more volume of steam, and gives more power with which to burst something if the throttle is opened wide suddenly during excitement.

It has been common to make all fire pumps with water plunger of only one-fourth the area of steam piston, with the idea that pump could thereby be more readily run at night, when steam was low. The capacity in gallons is thus reduced 25 per cent. as compared with a 3 to 1 plunger on the same steam cylinders.

Often, especially with large pumps, "4 to 1" construction is a mistake, and gives no additional security, although the pump might start and give a few puffs with 30 lbs. of steam on banked fires; because, if any pump of whatever cylinder ratio draws 50 or 100 horse-power of steam from boilers with dead fires, it can run effectively only a very short time (ordinarily, perhaps, 3 to 5 minutes), unless fires are first aroused to make fresh steam to replace that withdrawn.

Steam pressures stated above must be maintained *at the pump,* to give full speed and 100 lbs. water pressure. Pressure at boilers must be a little more to allow for loss of steam pressure between boiler and pump. Pumps in poor order, or too tightly packed, will require more steam.

The boiler horse-powers above are reckoned on the A. S. M. E. basis of 34½ lbs. of water evaporated from and at 212 degrees Fahrenheit as the unit of boiler horse-power. From 12 to 15 square feet of water-heating surface in the boiler is commonly assumed necessary for the generation of one horse-power.

Smaller boilers than called for above, if favorably set, and having excellent chimney draft, can sometimes be forced to nearly double their nominal capacity for a short run, as for fire service.

c. 250 gallons per minute is the standard allowance for a good 1⅛-inch (smooth nozzle) fire stream.

A so-called "Ring Nozzle" discharges only three-fourths as much water as a smooth nozzle of the same bore, and is not recommended.

From fifteen to twenty automatic sprinklers may be reckoned as discharging about the same quantity as a 1⅛-inch hose stream under the ordinary practical conditions as to pipes supplying sprinkler and hose systems respectively.

4. *Capacity.*

a. Plunger diameter alone will not tell how many gallons per minute a pump can deliver, and it is not reasonable to

continue the old time notion of estimating capacity on the basis of 100 feet per minute piston travel.

b. The capacity of a pump depends on the speed at which it can be run, and the speed depends largely on the arrangement of valves and passageways for water and steam.

c. It is all right to run fire-pumps at the highest speed that is possible without causing violent jar, or hammering within the cylinders. Considerations of wear do not affect the brief periods of fire service or test, hence these speeds are greater than allowable for constant daily duty.

d. Careful experiments on a large number of pumps of various makes at full speed, show that in a new pump with clean valves, and an air-tight suction pipe, and less than 15 feet lift, the actual delivery is only from $1\frac{1}{2}$ to 5 per cent. less than plunger displacement. This slip will increase with wear, and for a good average pump in practical use, probably 10 per cent. is a fair allowance to cover slip, valve leakage, slight short-stroke, etc.

e. Largely from tests, but partly from "average judgment," and recognizing that a long stroke pump can run at a higher rate of piston travel in lineal feet per minute than a short stroke pump, and that a small pump can make more strokes per minute than a very large one, the speeds given in the preceding table have been adopted as standards in fire service for direct acting (non-flywheel) steam pumps, which have the large steam and water passages herein specified.

f. Rated capacity is to be based on the speed in the preceding table, correcting the plunger displacement for one-half the rod area and deducting 10 per cent. for slip, short-stroke, etc.

Men sometimes ask why, if they can run a pump smoothly so as to get a delivery of 1,000 gals. per minute, we should not accept it as "a thousand gallon pump," irrespective of its suction valve area or its exhaust port area or the size of its cylinders.

To this we reply that *when new and favorably set* almost any pump built according to these specifications can run at a much greater delivery than here rated, but when lift is unusually high or suction pipe long, or when the pump takes its suction under a head, no pump can be run so fast as on, for instance, a 5-foot lift. A solid foundation is also a great aid in running a pump fast.

Standard 500-gallon pumps have often delivered 800 gallons, and 1,500-gallon pumps have delivered 2,000 gallons; but some margin must be allowed for unfavorable conditions and for deterioration as pump grows old, or for absence of an expert to get its utmost duty.

5. *Capacity Plate.*

a. Every steam fire pump must bear a conspicuous statement of its capacity securely attached to the inboard side of air chamber, thus:

NATIONAL STANDARD FIRE PUMP

16 X 9 X 12

CAPACITY

750 GALLONS PER MINUTE, OR
3 GOOD 1⅛-IN. SMOOTH NOZZLE
FIRE STREAMS

FULL SPEED

70 REVOLUTIONS PER MINUTE

NEVER LET STEAM GET BELOW
50 POUNDS, NIGHTS, SUNDAYS
OR AT ANY OTHER TIME

The name "Underwriter" has been largely used for a considerable time to designate the type of pump covered by the principal features of these specifications. While our preferences are against the use of this word as designating

any piece of apparatus objections will not be raised at the present time to its being continued on name plates in place of the words "National Standard," if manufacturers so desire.

b. This plate must have an area of not less than one square foot, and must be made of an alloy at least two-thirds aluminum and the remainder zinc. The letters must be at least one-half inch in height, plain and distinct, with their surfaces raised on a black background and buffed off to a dead smooth finish.

The name of pump manufacturer may also be placed on this plate, if desired.

c. A smaller plate of composition must be attached to steam chest bearing the size of pump, the shop number, and the name of shop in which the pump was built.

6. *Strength of Parts.*

a. The maker must warrant each pump built under these specifications to be at time of delivery, in all its parts, strong enough to admit of closing all valves on water outlet pipes while steam valve is wide open and steam pressure eighty pounds, and agree to so test it before shipment from his works.

b. The pump must be warranted so designed and with such arrangement of thickness of metal that it shall be safe to instantly turn a full head of steam on to a cold pump without cracking or breaking the same by unequal expansion.

7. *Shop Inspection.*

A systematic shop inspection must be given to each pump to ensure completed workmanship, and to prevent the use of defective parts, improper materials, or the careless leaving of foreign matter in any part of the cylinders or chests.

Several instances have occurred in which chisels, bolts, or core irons have been found in steam chests or steam cylinders. This has resulted in a serious crippling of the pump and in some cases requiring repairs to be made before pump could be used for fire purposes.

THE STEAM END.

8. *Steam Cylinders.*

a. These must be of hard, close iron with metal so distributed as to ensure sound castings and freedom from shrink cracks. The following are the minimum thicknesses acceptable:

14″ Diam.	7/8″ thick.		18″ Diam.	1″	thick.
16″ “	15/16″	“	20″ “	1 1/8″	“

b. The inside face of the steam cylinder heads and the two faces of the piston must be smooth surfaces, fair and true, so that if the piston should hit the heads it will strike uniformly all around, thus reducing to a minimum the chances of cramping the piston rod or injuring the pump.

c. All flanged joints for steam must be fair and true and must be steam-tight under 80 pounds pressure if only a packing of oiled paper 1/100 inch thick covered with graphite were used. Jenkins, “Rainbow” or equivalent packing of not exceeding 1/32 inch original thickness is acceptable. Oiled paper is not acceptable as a final packing, as it burns out.

For size of steam and exhaust pipes, standard flanges and bolting, see Art. 39.

The specifications originally required machine facing for all these surfaces. The art of machine molding from metal patterns with draw plates, etc., has, however, attained such excellence in certain shops that in regular practice “foundry faced” cylinder heads and piston faces can be made true and fair, and steam joints can be made tight under 80 lbs. pressure with a packing of oiled paper only 1/100 inch thick.

Under proper assurance that this precision can be obtained in regular practice at the shop in question, foundry finish may be accepted on cylinder heads and piston faces, steam chests and steam-chest covers.

In the case of *built-up pistons,* of separable form, it must be conclusively shown that the boring and finishing are carried on by such methods as will ensure the faces of pistons

being exactly square to the piston rod and exactly parallel to the cylinder head.

In the case of *solid pistons* the two faces must be machine faced, as proper parallelism cannot well be obtained by foundry methods.

Ordinary foundry finish secured by the old methods and wooden patterns is not acceptable and acceptance of any foundry-finish can only be secured after a special investigation of shop practices.

d. Heads at both ends of cylinder must be beveled off very slightly over a ring about 1 inch wide, or equivalent means provided to give steam a quick push at piston, should it stand at contact stroke.

9. *Bolts and Studs.*

a. The stress on bolts or studs in connection with steam cylinders must not exceed 7,500 lbs. per square inch under a test pressure of 80 lbs. steam, disregarding such initial strain as may be due to setting up. (Compute pressure area out to center line of bolts.)

No stud or bolt smaller than $\frac{3}{4}$-inch should be used to assemble parts subject to the strain of steam pressure as smaller bolts are likely to be twisted off.

10. *Yoke.*

a. The steam cylinders and water cylinders must be connected by such a form of yoke as requires no packing, a metal to metal joint at this connection being considered necessary. The piston rod stuffing box heads should concentrically fit the counter-bore of the yoke.

If packing is put into these joints, there is a chance of the steam and water ends getting out of alignment and leaking at the joint between cylinders and yoke.

11. *Steam Ports.*

a. The area of each exhaust steam passage, at its smallest section, must not be less than 4 per cent. of the area of the piston from which it leads.

This is a large increase over the size heretofore common, but indicator cards which we have taken from pumps of several different makes indicate this to be one of the points in which improvement is most needed to accommodate the high speeds at which fire pumps are always supposed to run, and this unrestricted exhaust aids very materially in giving steadiness to the jet of water.

b. Each admission port must be not less than 2½ per cent. of area of its piston, and to avoid wasteful excess of clearance, these passages should not be bored out larger in interior of casting than at ends or passage.

c. The edges of the steam-valve ports must be accurately milled, or chipped and exactly filed to templets, true to line, and the valve seat must be accurately fitted to a plane surface, all in a most thorough and workmanlike manner and equal to high-grade steam-engine work.

d. To guard against a piston ring catching in the large exhaust ports, these ports must have a center rib cast with cylinder at cylinder wall. See also Art. 13 *d.*

12. *Steam-clearance Space.*

a. Clearance (including nut-recess, counter-bore, and valve passages) must not exceed 5 per cent. for contact stroke or about 8 per cent. for nominal stroke (*i. e.,* contact stroke should overrun nominal stroke not more than one-half inch or not less than one-fourth inch, at each end).

b. The clearance space between face of piston and cylinder head must be reduced to smallest possible amount, and these contacting surfaces be flat, without projections or recesses other than the piston rod nut and its recess.

Some makers, with the idea that a fire pump need not be economical, have not taken pains to keep these waste spaces small.

Securing small clearance costs almost nothing but care in design, and is often of value, since at many factories boiler capacity is scant for the large quantity of steam taken by a fire pump of proper size.

13. *Steam Pistons.*

a. May be either built up or solid, as maker thinks best.

It is believed that "solid" (cored) pistons with rings "sprung in," are for fire-pumps much preferable to built-up pistons, since follower bolts *do* sometimes get loose.

b. Piston must be not less than four inches thick between faces. If solid, walls should be not less than ½ inch thick, and special care should be given to shop inspection to determine uniformity of thickness.

c. If built-up pistons are used, involving follower bolts, such bolts must be of best machinery steel, with screw thread cut for about twice the diameter of the bolt and fitting tightly its whole length.

d. The width of each piston ring must exceed the length of the large exhaust port by at least ¼ inch.

This is to avoid the possibility of piston ring catching in the port.

See also Art. 11, *d*.

14. *Steam Slide Valves.*

a. Slide valves must be machine fitted on all four of the outer edges, the exhaust port edges, and the surfaces in contact with rod connections.

b. The slide valve itself must have its steam and exhaust edges fitted up "line and line" with their respective steam and exhaust ports.

The adding of lap to these edges in lieu of lost motion is not acceptable further than a possible 1/32 of an inch to cover inaccuracies of edges.

c. The valves must be guided laterally by guide strips cast in steam chest, and these strips must be machine fitted. The lateral play at these surfaces should not exceed 1/16 inch. The height of these guide strips should not be less than ½ inch, measuring from valve seat.

The construction must be such as to absolutely preclude

the possibility of the valve riding up on top of this guide strip.

d. The valves must be guided vertically by the valve-rod itself, the inside end of which must be kept in alignment by the usual form of tail-rod guide.

The vertical play at these parts should not exceed $\frac{1}{8}$ of an inch.

e. The surface of valves must be machine faced and accurately fitted to a plane surface, and be steam-tight when in contact with the seat of steam valve.

15. *Steam Slide Valve Adjustment.*

a. The lost motion at the valves and the setting of them must be determined by a solid hub on the rod, finished in the pump shop to standard dimensions, so that no adjustment is possible after the pump is once set up.

This hub may be forged on the rod and then lathe-finished to standard dimensions, or it may be made by turning down a rod of the size of the hub. It is believed that Tobin bronze can be safely forged after a little experience, if care is taken to maintain the proper heat.

It is recognized that the practice of making adjustable valve tappets located outside of the steam chest is a good thing in a large pump in constant service and operated by a skilled engineer, but for the infrequently used ordinary fire pump, the utmost simplicity is desirable, and it is best not to tempt the ordinary man to readjust the valve gear.

The common form of lost motion adjustment consisting of nut and check nut at each end of the slide valve is not acceptable, as these nuts are liable to become loose and may be incorrectly reset by incompetent persons. A long, rectangular nut in the center of the valve is also not acceptable, as it can be moved out of adjustment. A solid hub made as a part of the rod is required, as it absolutely avoids the possibility of the hub becoming loose, an accident possible with a separate hub attached to the rod.

The amount of lost motion should generally be such that admission takes place at about $\frac{5}{8}$ of the stroke of the piston, *i. e.,* for 12-inch stroke R. H. valve will be about to open when L. H. piston has moved $7\frac{1}{2}$ inches to 8 inches from the beginning of stroke. When piston is at end of stroke the ports should be full open.

16. *Rock Shafts, Cranks, Links, Etc.*

a. Rock shafts must be either forged iron, forged steel, or cold rolled steel. Cast-iron is not acceptable. The following are the minimum diameters acceptable:

500 gallon pump............	$1\frac{1}{2}$ in.
750 gallon pump............	$1\frac{3}{4}$ in.
1000 gallon pump............	2 in.
1500 gallon pump............	2 to $2\frac{1}{4}$ in.

b. The rock shaft bearings must be bushed with bronze and the bushings pinned firmly in place. The length of each of these non-corrosive bearings must be not less than 4 inches.

c. Rock shaft cranks, valve rod heads, valve rod links, and piston rod spools or crossheads may be wrought iron or steel forgings, or steel castings. If of a heavy, strong pattern, these parts, with the exception of valve rod links, may be of semi-steel or cast iron.

d. The sectional area of all connections between rock shaft cranks and valve rod must be such as to give a tensile or compressive strength substantially equal to that of the valve rod.

17. *Valve Motion Levers.*

a. The valve motion levers must be steel, wrought iron, or steel castings. Cast iron is not acceptable. Steel castings, if used, must be deeply stamped with the name of the makers, with letters one-eighth inch high, near the upper end of each lever, where it can easily be seen,—thus "...... *Steel Castings.*"

Cast-iron arms, if bulky enough to be safe against external blows, are awkward in shape. The sectional area necessary for any arm depends upon the means provided for preventing a sidewise strain on the lever, due to rotation of piston or friction of its connection to piston rod. The spool or crosshead on the piston rod should be so designed that no sidewise strain can be thus produced in the lever.

b. The levers must have a double or bifurcated end at crosshead.

The double end is less likely than a single end to put an undue strain on the lever as the rod turns, and is also less likely to give trouble from lack of lubrication or from a loosening of any small parts, and has proved to be the most satisfactory arrangement.

18. *Valve Motion Stand.*

a. The valve motion stand must be securely dowel-pinned to the yoke castings, to prevent any movement after once adjusted.

19. *Cushion Valves.*

a. Cushion-release valves regulating the amount of cushion steam retained at ends of stroke must be provided.

b. The cushion release must be through an independent port as shown in Figs. 2 and 3, so located as to positively retain a certain amount of cushion steam.

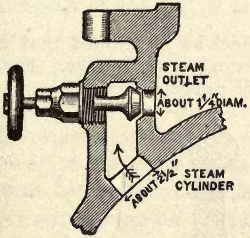


FIG. 2

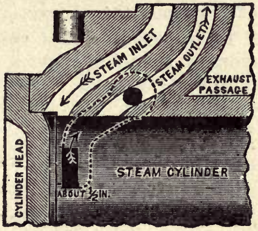


FIG. 3

The old form of cushion release through bridge between ports is not acceptable. This form, while leading into the exhaust passage as formerly, differs by starting from a small, independent port (about ½ inch wide x 2½ inches long) through the cylinder wall, located about ⅜ or ½ inch back from the cylinder head. (The exact position for affording the best action has to be determined by experiment with each different make of pump, as it depends somewhat on the extent of clearance space and on the point of closure of exhaust by piston and somewhat on the weight of reciprocating parts.)

This style of cushion port makes the pump safer in case

cushion valves are unskillfully left open too wide and tends to prevent a pump from pounding itself to pieces in case of a sudden release of load, as by a break in suction or delivery mains, or by a temporary admission of air to suction pipe.

Pumps made with this form of cushion release have given very satisfactory results, and if the ports are properly located there will be no rebound of piston.

c. Cushion valves must be always provided with hand-wheels marked as per sketch, for the reason that very few men in charge of fire pumps are found to clearly understand or to remember their use.

FIG. 4

The lettering must be very open, clear and distinct, not liable to be obscured by grease and dirt, and of a permanent character.

It is desirable that spindle or wheel be so formed that a monkey wrench can get a grip to open a jammed valve. Fig. 5 shows the stem flattened for this purpose.

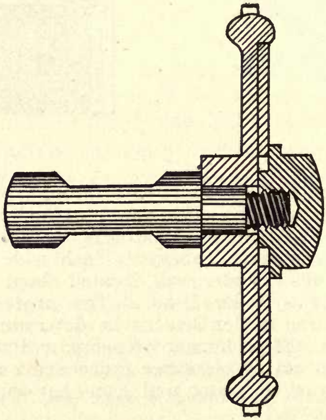


FIG. 5

d. The valve and stem of cushion valve must be in one piece without any swivel joint.

Swivel joints are apt to come apart and make it impossible to operate the valve.

20. *Piston Rods.*

a. Piston rods for their entire length must be of solid Tobin bronze, and the distinguishing brand of the manufacturers of this metal must be visible on at least one end of each rod.

b. The sizes must be not less than in table below.

Size of Pump.	500 Gal.	750 Gal.	1,000 Gal.	1,500 Gal.
Diameter of rod....	2 Inch.	2¼ Inch.	2⅜ Inch.	2½ Inch.

c. The size and form of connection of rod to piston plunger and cross-head must be such that the stress in pounds per square inch at bottom of screw thread, or at such other point of reduced area as receives the highest tensile strain, shall not exceed 8,000 lbs. per square inch, when the steam pressure acting on the piston is 80 lbs. per square inch.

d. Piston rod nuts, in both steam and water ends, must be tightly fitted, and preferably of a finer thread than the United States Standard. This is to avoid as much as possible the unnecessary weakening of the rod at the bottom of the thread, and to reduce the tendency of the nut to work loose.

In practice 8 threads per inch has been found to give good satisfaction.

e. In addition to a tightly fitting nut, some reliable device must be provided, in both steam and water ends, for absolutely preventing these nuts from working off.

Fig. 6 shows one form of such a locking device and illustrates the kind of security desired.

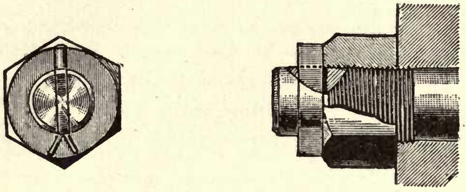


FIG. 6

This device combines the advantage of a taper key and a split pin, and the elongated key-slot gives sufficient leeway to always insure that the key can be driven up tight against the nut and thus prevent it from even starting to work off. Other methods will be approved in writing, if found satisfactory.

21. *Valve Rods.*

a. Valve Rods for their entire length must be of solid Tobin Bronze, with sizes not less than in table below.

Size of Pump.	500 Gal.	750 Gal.	1,000 Gal.	1,500 Gal.
Diameter of rod....	1 Inch.	1⅛ Inch.	1⅛ Inch.	1¼ Inch.

b. The net area of valve-rod at its smallest section subject to tensile stress, must not be smaller than at bottom of U. S. standard screw thread on rod of diameter given above.

The construction of this rod as affecting lost motion at slide valve is specified under Article 15.

22. *Stuffing Boxes.*

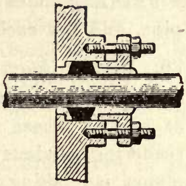


FIG. 7

a. All six stuffing boxes must be bushed at the bottom with a brass ring with suitable neck and flange, and the follower or gland must be either of solid brass, or be lined with a brass shell 3/16-inch thick, having a flange next the packing, as shown in the sketch.

The bottom of stuffing boxes and the end of glands should taper slightly towards the center as per sketch.

b. These glands should be strong enough to withstand considerable abuse, so as not to break from the unfair treatment of unskilled men.

23. *Pressure Gage.*

a. A pressure gage of the Lane double tube spring pattern with 5-inch case must be provided and attached to the steam chest inside the throttle valve.

The dial of gage should be sealed to indicate pressures up to 120 lbs. and be marked "STEAM."

This kind of gage is used on locomotives and is the best for withstanding the vibration which causes fire pump gages to be often unreliable. Moreover, this double spring is safer against freezing.

24. *Drain Cocks.*

a. Four brass drain cocks, each with lever handle and of one-half inch bore, are to be provided, and located one on each end of each steam cylinder.

Care should be taken to select a pattern of cock whose passageway is the full equivalent of a ½-inch hole. Some patterns of ½-inch commercial cocks, although threaded for ½-inch pipe thread, have but a ¼-inch hole through them. Such are not acceptable.

25. *Oiling Devices.*

a. A one-pint hand oil pump, to be connected below the throttle, and a one-pint sight feed lubricator, to be connected above the throttle, must be furnished with each pump.

b. Oiling holes must be provided for all valve motion pins, and for each end of both rock shafts.

26. *Stroke Gage.*

a. A length-of-stroke-index must be provided for each side of pump. These must be of simple form for at all times rendering obvious the exact length of stroke which each piston is making, and thus calling attention to improper adjustments of cushion valves or stuffing boxes.

b. The gage piece over which the index slides must have deep, conspicuous marks at ends of nominal stroke, and also light marks at extreme positions; it need contain no other graduations.

c. This stroke index must be rigidly secured to cross-head in such a way that it cannot get loose or out of adjustment.

THE WATER END.

27. *Water Cylinders.*

a. These must be of hard, close iron with metal so distributed as to ensure sound castings, and freedom from shrink cracks.

b. The design should be along lines best calculated to resist internal pressures so as to avoid as much as possible the need of ribs for stiffening.

c. They must be capable of withstanding, without showing signs of weakness, the pressures and shocks due to running under the conditions mentioned in Chapter "Tests for Acceptance," Art. 48-54.

The suction chamber should be able to withstand a water pressure of 100 lbs.

Although suction chambers are not regularly subject to a pressure, it is sometimes desired to connect them to public water supplies, and where foot valves are used there is a chance of getting pressure on the suction, so that ample strength is necessary.

Foundry finish may be permitted on the joints at water cylinder heads and at hand-pole plates, provided surfaces

are so true that a rubber packing not over 1/16 of an inch in thickness is sufficient to secure perfect tightness.

d. Conveniently placed hand-holes of liberal size must be provided for the ready examination and renewal of valve parts at the yoke end of water cylinders and in the delivery chamber.

This will necessitate holes not less than 6x8 inches, or its equivalent, for the two largest-size pumps, and holes proportionately as large for the 500 and 750-gallon pumps. The easy access to the valve parts is of vital importance, and must receive careful attention.

e. The thickness of metal for cylinder shell, valve decks, partitions, ribs, etc., will depend largely upon the form of construction, but, in a general way, to establish safe minimums for the average water cylinder, of nearly cylindrical form, whose flat surfaces are stiffly ribbed, we submit the table below.

Size of Pump.	500 Gal.	750 Gal.	1,000 Gal.	1,500 Gal.
	Inches.	Inches.	Inches.	Inches.
Thickness of cylinder shell when of nearly cylindrical form............	7/8	1	1 1/8	1 1/4
Thickness of valve decks when well ribbed	1 1/4	1 1/4	1 1/4	1 1/4
Thickness transverse partition, depending on ribbing ...	1 1/4 to 1 1/2	1 1/4 to 1 1/2	1 1/2 to 2	1 1/2 to 2
Thickness of longitudinal partition, depending on ribbing............	1 1/4 to 1 1/2	1 1/4 to 1 1/2	1 1/4 to 2	1 1/2 to 2
Thickness of ribs...	3/4	7/8	1	1
Thickness of suction chamber	5/8	3/4	3/4	7/8
Thickness of delivery chamber	7/8	1	1 1/8	1 1/4

Lighter construction than herein specified will not be regarded as satisfactory, and any construction will be finally passed upon on examination of drawings.

f. The bolting of all parts of the water end is to be of such strength that the maximum stress at bottom of screw thread will not exceed 10,000 lbs. per square inch (disregarding for the moment the initial stress due setting up nuts) for a water pressure of 200 lbs. per square inch, computed on an area out to center line of bolts.

No stud or bolt smaller than $\frac{3}{4}$-inch should be used to assemble parts subject to the strain of water pressure, as smaller bolts are likely to be twisted off.

Although these pumps are not expected to be designed for a regular working water-pressure of 240 or 320 lbs., it is expected that bolts, shells, rods, etc., will be figured to stand this comparatively quiet, temporary high pressure, exclusive of further allowance for initial strain due setting up of bolts, with a factor of safety of at least four.

This high test pressure is analogous to the custom of proving all common cast-iron water pipes to 300 lbs. and all common lap-welded steam pipes to 500 lbs. per square inch, and common water-works gate valves to 400 lbs., even though these are to be regularly used at much less pressure.

We are assured that castings no heavier than at present used by the best makers will stand this test, *if properly shaped and liberally bolted.*

g. For requirements for stuffing boxes, see Art. 22.

28. *Water Plungers and Bushings.*

a. The "inside plunger and bushing" is preferred for all situations where the water is free from grit or mud.

b. Water plungers must be of solid brass or bronze, and the bushing in which they slide must also be of brass or bronze. The composition of the plunger and its bushing should be of very hard, though dissimilar alloys, to ensure good wearing qualities.

For material and size of piston rods and lock for nuts, see Art. 20.

With poor alignment or bad workmanship or lack of skill in mixing the alloys, brass plungers are liable to score and give trouble; but with proper selection of alloys and true cylinders accurately aligned, they can be made to run all right wherever iron ones can. It is quite a fine point to get these wearing surfaces just right; and *this is wherein the experience, skill and shop practice of one maker is likely to be much superior to that of another working under the same specification.*

c. The length of machined cylindrical bearing within the partition must be not less than 2 inches. The plunger bushing must have a faced seat transverse to its axis against partition, forming a water-tight ground joint not less than one-half inch wide.

Any rubber gasket or other compressible packing for making this joint water-tight is not acceptable.

d. The construction of bushing and hole in partition must be such that a cylindrical shell for use with a packed piston can be interchangeably inserted in its place and secured by the same bolts.

This can readily be arranged and enables a packed piston to be inserted in place of a plunger subsequent to the installation of the pump with a minimum of expense, should this become desirable from change of conditions at any future time.

e. Small transverse grooves cut within the sliding surface of the plunger bushing, with a view to lessen the leakage, are not acceptable.

Although a slight advantage in this respect for clean water, they are a disadvantage on the whole, as dirt catches in them in the ordinary situation and cuts the plungers.

29. *Standard Dimensions of Plungers and Plunger Bushings.*

a. To bring all these expensive parts to the same standard of weight and bearing surface, the following dimensions are specified as the least that will be acceptable. These are based on a length of plunger which uncovers the bushings one inch at end of nominal stroke.

SOLID BRONZE PLUNGERS AND BUSHINGS.

Size of Pump.	500 Gal.	750 Gal.	1,000 Gal.	1,500 Gal.
Plunger.				
Diameter........	7 or 7¼-in.	9-in.	10or10¼-in.	12-in.
Length..........	17-in.	17 "	18-in.	24 "
Thickness of transverse petition..	⅝ "	⅝ "	¾ "	¾ "
Thickness next to partition......	½ "	⅝ "	⅝ "	¾ "
Thickness next to end...........	5/16 "	⅜ "	⅜ "	½ "
Number of ribs .	4 "	4 "	6 "	6 "
Thickness of ribs.	5/16 "	5/16 "	⅜ "	⅜ "
Bushing.				
Length..........	7 "	7 "	8 "	10 "
Thickness at end .	5/16 "	⅜ "	⅜ "	½ "
Thence tapered evenly to a thickness next to bearing of not less than..........	½ "	⅝ "	⅝ "	¾ "
Thickness at the center bearing not less than...	¾ "	¾ "	¾ "	13/16 "

30. *Water Pistons and Bushings.*

a. The "water piston with fibrous packing" is preferred for many situations in the West or South, or for water containing grit or mud, like that of the Ohio River; and, for the comparatively few cases where pump pressure governors are used, the packed piston will give better service and longer wear.

b. The removable bushing or cylinder in which this piston works must be of solid bronze.

c. As stated in Art. 28 *d*, this bushing should be so constructed as to be readily interchangeable with the bushing of the inside plunger type.

d. The length of bushing must be such that the ends of piston will barely come short of the edges of cylinder at contact stroke and not uncover.

e. The thickness of the cylindrical bushings must be not less than as given in the following table:

BUSHINGS FOR PACKED WATER PISTONS.

Size of Pump.	500 Gal.	750 Gal.	1,000 Gal.	1,500 Gal.
Solid Bronze.				
Thickness at extreme end.....	7/16-in.	½-in.	½-in.	9/16-in.
Tapered evenly from end to a thickness next to bearing of not less than......	9/16 "	⅝ "	11/16 "	¾ "
Thickness at center bearing, at least..........	¾ "	¾ "	¾ "	13/16 "

f. In other respects, the specifications for plunger bushings, already given in Art. 28, will apply to the above.

g. The water piston used in the shell described above must expose not less than 2 inches in width of fibrous packing, and must be of bronze, with disc and follower accurately turned to a sliding fit, so that the leakage past it will be a minimum, even when no fibrous packing is in place. There must be at least 2 inches in length of metallic bearing on both disc and follower.

The follower must be accurately centered and fitted to hub of piston, so that alignment will not be disturbed if taken apart.

h. The water piston must be of simple and strong construction, with follower bolts tightly fitted, and with fibrous packing so cut as to prevent by-passing.

i. All materials used in construction of piston, except packing, must be brass, bronze or other non-corrosive metal.

j. Bushing studs must be of Tobin Bronze, and of such size and number that the maximum stress at the bottom of the screw thread shall not exceed 10,000 lbs. per square inch, in the event of plunger becoming fast in the bushing with 80 lbs. of steam in the steam cylinders.

k. For each bushing stud there must be provided a composition nut and check nut.

l. All minor parts exposed to the action of water in water cylinder, that are not herein specified, must be of brass, bronze or other non-corrosive material.

31. *Pump Valves.*

a. All the suction and discharge valves in any one pump must be of the same size and interchangeable.

b. There must be a clear space around each rubber valve, between it and the nearest valve, equal to at least one-fourth of the diameter of the valve, or between it and the wall of the chamber of at least one-eighth of the diameter of the valve.

c. These valves must be of the very best quality of rubber, of medium temper, with a face as soft as good wearing quality will permit.

They must be double-faced, so they can be reversed when one face is worn.

The quality of rubber is almost impossible of determination by brief inspecton or by chemical analysis. The relative amount of pure gum and of cheaper composition may vary, or good material may be injured by defective vulcanization. The only safe way to secure excellence and uniformity is for the pump manufacturer to test samples of each new lot under severe duty (as by a week's run in a small special pump, with say, 150 pounds pressure and heavy

water hammer, or by some equivalent means) and to furthermore require the rubber manufacturer to mould a date mark as "(Name of pump manufacturer, lot 201—April 3, 1904)" on the edge of every valve, by which the pump manufacturer can keep track of those which prove defective.

32. *Size and Number of Pump-Valves.*

a. The diameter of the disc of rubber forming the valve must not be greater than 4 inches or less than 3 inches. Three and a half inches diameter is probably the most favorable size, but is not insisted upon.

There is some confusion between different shops about designating size of valves. The practice is here adopted, which is much the most widely used, of naming the diameter of the disc of rubber which covers the ports, and it is hereby specified that this shall be about ½ inch greater than the diameter of the valve-port circle which it covers, thus affording about ¼ inch over-lap or bearing for the rubber disc all around its edge.

If valves are larger than 4-inch there is an increased tendency to valve-slam at the very high speed at which the pump is designed to run, and if valves are smaller than 3 inches diameter the greater number tends to unnecessary multiplication of parts, and the ports being so small are a little more liable to become obstructed by rubbish.

b. The thickness of the rubber valve must in no cases be less than ⅝-inch.

33. *Suction Valve Area.*

a. The total lift of suction valves must not exceed ½-inch.

b. The net suction valve port area and the total suction valve outlet area under valves lifted ½ inch high must not be smaller than the figures given in the table below:

(1) Length of Stroke (in inches)	(2) Greatest No. revolutions per minute.	(3) Corresponding Piston travel per minute.	Approx. actual max. Piston velocity at full speed, per column (3) x 2.2.		(6) Net Suction Valve-port area regarded necessary for this speed. Per cent. of Plunger area.	(7) Total Suction Valve Outlet AREA under Valves lifted ½-inch high.	(8) Discharge Valve Area.
			(4) Feet per min.	(5) Feet per sec.			
12	**70**	**140**	308	5.1	**56%**	**56%**	⅔ of Suction Valve. Area
16	60	160 ft.	352	5.9	64%	64%	

By "valve-outlet area," we mean the vertical cylindrical surface over the outer edge of the valve ports, *i. e.*, the distance L multiplied by the circumference at the outer edge of the valve ports *C.* Thus for a 4-inch valve, with ports inscribed in a 3½-inch circle, whose circumference is 3.5x3.1416=11 inches; the valve "outlet area" for ½-inch lift would be 5½ inches.

The actual velocity of piston during the middle portion of stroke is from 2.0 to 2.4 (average 2.2) times as great as the piston travel per minute (as determined in experiments by Mr. J. R. Freeman on several duplex pumps of different manufacture). This is because each piston stands still nearly half the time, or while its mate is working, and, moreover, moves more slowly near start and finish of stroke. The words

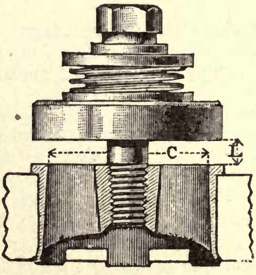


FIG. 8

"piston speed" are commonly incorrectly used, and refer to "piston travel." A clear understanding that the actual piston speed is *more than twice as great* leads to more generous valve design.

Large aggregate valve areas are necessary for pumps designed to run as fast as these, and experience has shown that to prevent valve slam at high speed and to accommodate high suction lifts, it is just as important to have a large "valve outlet area" as to have a large area of valve port.

It is valve slam or water hammer which commonly limits the highest speed at which a pump can be run. This water hammer may originate from the pulsations in a long or small suction pipe. The vacuum chamber lessens it, but there is commonly some point of high water in the vacuum chamber that will give much smoother action than any other.

Valve slam in this style of pump is caused chiefly by the short rebound of the steam piston against the elastic steam cushion at the end of the stroke. This in turn snaps the valves down with a jump when the speed is high. Dividing this impact or slam on numerous valves of low lift, tends to break up and lessen the shock, therefore with valves of the size and style used in fire pumps, other things being equal, the less they have to rise and drop to let the water through them, the less will be the valve slam. This height of rise and drop is governed by the circumference rather than the port area. Experience and practice has shown that a ½-inch limit of lift is reasonable and does ensure a smooth working pump under all ordinary conditions.

c. The following table gives minimums for aggregate valve port area and aggregate valve outlet area for the different size plungers, figured on a basis of 56% of plunger area for a 12-inch stroke, and 64% for a 16-inch stroke.

	Size of Pump.	500 Gal.	750 Gal.	1,000 Gal.	1,500 Gal.
1	Diameter of plunger. Inches	7¼″	9″	10″	12″
2	Area of plunger in square inches ...	41.28	63.62	78.54	113.10
3	56% of plunger area, or minimum aggregate valve port area allowed per section. Square inches	23.11	35.63	43.98	64% = 72.38
4	Minimum aggregate valve port circumference, allowed per section. Inches	46.22	71.26	87.96	144.76
5	Minimum aggregate valve outlet area allowed per section for valves lifted ½-inch high. Square inches....	23.11	35.63	43.98	72.38

d. If we consider using any one of the three sizes of valves below, whose port areas may be assumed approximately as

Diam. Valve.	Diam. of Valve Port Circ.	Circ. of V. C. Circle.	Valve Port Area (Net). Square Inches.
3″	2½″	7.85″	3.5
3½″	3″	9.42″	4.7
4″	3½″	10.99″	6.3

given, then the necessary number of valves per section will be as in the table following:

Size of Pump.	500 Gal.			750 Gal.			1,000 Gal.			1,500 Gal.		
Sizes of Valves.	3″	3½″	4″	3″	3½″	4″	3″	3½″	4″	3″	3½″	4″
Necessary number of valves to satisfy (4) under *c*	6	5	5	9	8	7	11	10	8	19	16	14
Necessary number of valves to satisfy (3) under *c*	7	5	4	10	8	6	13	10	7	21	16	12

The exact number and size of valves will, however, not be insisted upon provided the aggregate valve area and the aggregate valve outlet area for each section is not less than that given in the table under *c* for the limiting lift of ½ inch.

Manufacturers will note that with the established lift of ½ inch, the 3½-inch valve will permit a valve outlet area more nearly equal to its port area than will either the 3-inch or 4-inch valves, and a *relatively* less number of valves will satisfy the specifications.

34. *Delivery Valves.*

a. The total lift of delivery valves must not exceed one-half inch.

This is to avoid valve-slam, as explained in Art. 33.

b. The aggregate valve-port area should be restricted to about two-thirds the suction-valve area.

A small restriction of water-way through the delivery valves steadies the action of the pump and tends to prevent undue pulsations of pressure in the delivery pipe or fire hose. Fewer delivery valves than suction valves are, therefore, preferred, and if extra holes in the delivery deck are cast for shop purposes these had better be plugged than fitted with valves.

The suction valves require more generous port-circumference and port-area than delivery valves, because when a pump has to suck its supply through a considerable height or through a long pipe there should be the least practicable waste of the atmospheric pressure in getting the water into the plunger chamber, or in retarding it from following the plunger in full contact. With the water once into the plunger chamber there is plenty of steam pressure available to force it out through the delivery valves.

35. *Valve Springs, Guards and Covers.*

a. All valve springs must be of the best spring brass wire, and must be coiled on a cylindrical arbor.

Conical valve springs are not approved because the strain is not uniform throughout spring, thereby increasing the liability to breakage and the chance of their getting out of center and becoming "hooked up."

b. The valve spring must be held centrally at its top by resting in a groove in valve guard, substantially as shown in Fig. 9.

c. A light, rustless metallic plate must be interposed between the bottom of the spring and the rubber valve, and must be the full area of the valve. This plate must also be formed with a raised bead to guide the spring at the bottom.

The weight of this plate should be small, for the inertia of the lifting parts of the valves should be the least possible, to permit quick action and to avoid pounding.

d. For the average condition of a 10 or 15-foot lift, the stiffness of suction valve springs should be such that a force of about one pound per square inch of net port area will lift valve $\frac{1}{4}$-inch off its seat.

The springs on the delivery valves should ordinarily be from two to three times as stiff as just specified, but any other reasonable degree of stiffness which is proved to work well in practice will not be objected to.

For suction under a head, the greater snap with which water enters the plunger chamber when thus pushed in by say twice the atmospheric pressure, renders it difficult to avoid water hammer at high speed. Extra stiff suction valve

springs will commonly aid in controlling this and should be used wherever pumps are to work under a head.

An approved type of indicator water gate on the suction pipe near the pump, which can be partly closed, will enable the pump to run quietly at high speed. Such a gate is an extra not included in price of the pump.

36. *Sticking of Valves.*

a. Steam fire pumps should be started to limber them up *at least* once a week.

Although vulcanized India-rubber is much the best material yet used for fire-pump valves, unfortunately the brass is sometimes corroded by the free sulphur contained in the rubber, so that if the pump is left standing for several weeks the rubber valve discs may become stuck to their brass seats, and, if suction has a high lift, there may not be vacuum enough to tear all the suction valves open when pump is started.

37. *Valve Seats.*

a. All water valve seats must be of bronze composition. They may be either screwed into the deck on a taper or forced in on a smooth taper fit. With either arrangement, the seat must be either flanged out on the under side all the wall round or be provided with a substantial lug opposite each rib, these lugs being expanded out after the valve is inserted.

If the valve seats are not expanded after being put in place, there is a possibility that now and then a valve seat will work loose and come out, thus crippling the pump.

b. The under side of the valve deck must be rounded over to give good bearing for the expanded part of the seat.

c. Three-inch valves must have four or five ribs, three-and-a-half-inch valves five or six ribs, and four-inch valves six ribs.

Enough ribs must be provided to give proper support to the rubber valve, but too many are objectionable, as small ports would be liable to obstruction by refuse.

d. The edges of the valve-seat ports must be moderately

rounded over to remove such sharp edges and points as would be liable to cut or damage the rubber valve when under pressure.

38. *Valve Stems.*

a. All valve stems must be of $\frac{3}{4}$-inch Tobin bronze and of the fixed type, and must have the guard fastened on by one of the methods shown by Figs. 9 and 10.

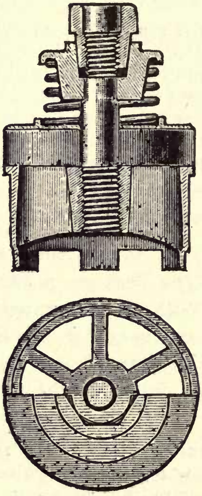


FIG. 9

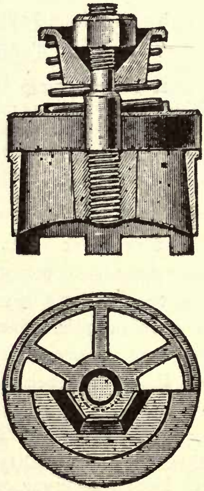


FIG. 10

Other methods may be approved, in writing, if found by test and experience to have especial merit.

b. These stems must be screwed into the seats on a straight, tightly fitting thread, and the lower end then well headed over into a countersink. The valve guard and nut must be of composition.

In Fig. 9 the upper part of the stem is slabbed off on two opposite sides and fits a corresponding hole in the guard.

The guard, therefore, cannot turn The outside of the special nut is fitted on a taper to the inside of the guard, and the nut tapped out to fit the ⅝ U. S. thread on the stem.

The action of the valve, whether with the spring or without, tends to drive these taper fits together, producing a frictional lock similar to that of a friction clutch; and although the nut may be loose on the thread, it cannot possibly work off.

It will be apparent that the taper fit on the nut must be so made as to always bear on the taper fit in the guard, and not bottom in the guard.

It is believed that with the present screw machine practice in shops of to-day these small parts can readily be turned out accurately and cheaply in large quantities. The nuts and guards made in any one shop must be exactly of standard dimensions, so that the product of different periods will be interchangeable.

The taper should be about one inch to one foot. With this taper the nut can be readily turned in or out, but there is friction enough to hold the guard and nut together even if the spring is off.

In Fig. 10 the top of the guard is recessed in the form of a hollow inverted pryamid of six sides, to correspond to a hexagonal nut. The angle of two opposite sides of this recess, which should be about 75 degrees, will both surely lock the nut and still permit of its being turned with a wrench.

The guard is kept from turning by slabbing off the stem, in the same manner as described and shown in Fig. 9.

To facilitate the removal of the nut, the edges should be slightly champfered. An unfinished nut simply drilled and tapped is all that is desired. Any hexagonal or square nut within the size of the tapered recess will be locked.

With this construction, the nut cannot turn in either direction without compressing the spring and is therefore locked, and in the event of the spring breaking or being left off, the nut is well protected in its recess from the possible turning effects of water currents, and experiments have shown that it will still stay in place.

With machine molding it will be possible to make these guards complete in foundry, requiring no machine work further than a possible broaching out of hole to fit the stem, as a fairly good fit is necessary.

While both of these devices are effective, even though not

tightened down to a shoulder, they should be so tightened for greater safety and to fix the lift at the half-inch limit.

39. *Pipe Sizes.*

a. Water and steam pipe connections must have standard flanges to connect with pipes of the sizes given below.

Size of Pump. Gals. per Min.	Diameter of Suction Pipe. Inches.	Diameter Discharge Pipe Inches.	Steam Pipe.	Exhaust Pipe.
500	8	6	3	4
750	10	7 or 8*	3½	4
1,000	12	8	4	5
1,500	14	10	5	6

*Eight-inch preferred, this being the more common size for valves, fittings and pipes.

These suction pipe sizes, although larger than common for trade pumps of the same size, are believed to be amply justified by experience, and exert a powerful influence toward enabling the pump to run smoothly at high speed with water cylinders filling perfectly at each stroke. No defect is more common than restricted suction pipes.

b. A single suction entrance at the end of the pump is to be provided unless otherwise specified by the purchaser.

Some situations render desirable side suction entrances, for permitting drafting water from two different sources of supply. These additional openings are to be considered as extras. Ordinarily, the purchaser can provide for such situations by proper piping at the single end suction entrance.

If there is to be but one suction opening on casting, this had best be at centre, for the reason that, if suction pipe ever gets to leaking air, this aid stands a better chance of being distributed equally to the two plungers, and has less tendency to make the pump run unevenly.

c. Standard flanges and standard bolt layouts as adopted by the Master Steam Fitters, July 18, 1894, must be used on all the above pipe connections, as per table.

SCHEDULE OF STANDARD FLANGES.

Size of Pipe x Diameter of Flange. Inches.	Diameter of Bolt Circle. Incnes.	Number of Bolts.	Size of Bolts. Inches.	Flange Thickness at Edge. Inches.
3 x 7½	6	4	⅝ x 2½	13/16
3½ x 8½	7	4	⅝ x 2½	⅞
4 x 9	7½	4	¾ x 2¾	15/16
4½ x 9¼	7¾	8	¾ x 3	15/16
5 x 10	8½	8	¾ x 3	15/16
6 x 11	9½	8	¾ x 3	1
7 x 12½	10¾	8	¾ x 3¼	1 1/16
8 x 13½	11¾	8	¾ x 3½	1⅛
9 x 15	13¼	12	¾ x 3½	1⅛
10 x 16	14¼	12	⅞ x 3⅝	1 3/16
12 x 19	17	12	⅞ x 3¼	1¼
14 x 21	18¾	12	1 x 4¼	1⅜

Do not drill bolt holes on center line, but symmetrically each side of it.

On steam and exhaust openings loose flanges threaded for wrought iron pipe must be provided.

Where the situation will not permit of a standard flange on exhaust opening for lack of room, a special flange threaded to fit the proper size wrought-iron pipe may be used.

40. *Air and Vacuum Chambers.*

a. Air and vacuum chambers in accordance with the sizes given in the following table must be provided with all pumps. If the air chamber is cast iron, the pump manufacturers must warrant that it has been subjected to a hydraulic test of 400 lbs. per square inch before it is connected to pump.

It is to be thoroughly painted inside and out to diminish its porosity.

SIZE OF VACUUM AND AIR CHAMBERS.

	Vacuum Chamber is to contain :—	Air Chamber is to contain :—
500-Gallon Pump.	13 Gallons.	17 Gallons.
750 " "	18 "	25 "
1,000 " "	24 "	30 "
1,500 " "	30 "	40 "

The air chamber, combined with connections for discharge pipe, relief valve, and hose valves, should be carefully designed to make the whole weight as small as possible. Keeping this weight down makes the pump run steadier and brings less strain on the flanges at high speeds.

An air chamber of hammered copper and warranted tested under a hydraulic pressure not less than 300 lbs. per square inch is a little better than cast-iron, as it holds air better, and, being lighter, it wrenches and strains the pump less when running fast and shaking, but because it costs from $25 to $50 more than cast-iron, it is not often adopted.

b. The vacuum chamber must be attached to the pump in the most direct way practicable, but provision must be made for attaching it in such manner as not to prevent readily taking off the piston heads.

c. Every vacuum chamber should be provided on one side near the top with a ¼-inch pipe tap plugged. This to be used for attaching a vacuum gage if desired.

41. *Pressure Gage.*

a. A pressure gage of the Lane double tube spring pattern with 5-inch case, must be provided with the pump, and connected near to inboard side of air chamber, as shown in Fig. 12, by a ¼-inch cock, with lever handle.

The dial of this gage should be scaled to indicate pressures up to 240 lbs. and be marked "WATER."

This kind of gage is used on locomotives and is the best for withstanding the vibration, which causes fire-pump

gages to be often unreliable. Moreover, this double spring form is safer against freezing.

42. *Hose Valves.*

a. Hose valves must be attached to the pump (and included in its price) as follows:

For the 2 stream or 500-gal. pump, 2 hose valves.
For the 3 stream or 750-gal. pump, 3 hose valves.
For the 4 stream or 1,000-gal. pump, 4 hose valves.
For the 6 stream or 1,500-gal. pump, 6 hose valves.

These are to be 2½-inch straightway brass valves, without cap, and similar and equal in quality to those made by the Chapman Valve Company, the Ludlow Valve Company, or the Lunkenheimer Company.

The hose-screw at end of these valves is to be fitted to a hose coupling furnished by the customer, or where this cannot be procured may be left with the thread uncut.

To accommodate locations where all the lines of hose must lead off from one side of the pump—makers can furnish a spool piece or special casting to which the hose valves can be attached—but this is an extra not included in the regular price.

43. *Safety Valve.*

a. A safety or relief valve of the Ashton, Crosby, American or other make agreed upon in writing with this office, is to be regularly included in the price, and is to be attached to each pump; preferably extending horizontally inboard from base of air chamber, as shown in Fig. 12, so that its hand-wheel for regulating pressure is within easy reach. This hand-wheel must be marked very conspicuously, as shown in sketch.

b. This valve is to be set ordinarily at a working pressure of 100 pounds to the square inch, and is to be of such capacity that when set at 100 pounds it can pass all the water discharged by the pump at full speed; at a pump pressure not exceeding 125 pounds per square inch.

FIG. 11

For	500-gallon	pump, a	3	inch valve.
For	750-gallon	pump,	$3\frac{1}{2}$	inch valve.
For	1,000-gallon	pump,	4	inch valve.
For	1,500-gallon	pump, a	5	inch valve.

The relief valve must discharge in a vertical downward direction into a cone or funnel secured to the outlet of the valve. (See Art. 44.)

The valve must be so attached to the delivery elbow and discharge cone by flange connections as to permit of its

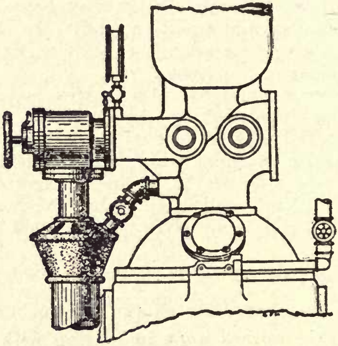


FIG. 12

ready removal for repairs without disturbing the waste piping.

44. *Discharge Cone.*

a. This cone should be so constructed that the pump operator can easily see any water wasting through the relief valve, and its passages should be of such design and size as to avoid splashing water over into the pump room.

b. The cone must also have a one-inch tapped connection for the air vent pipe required by Art. 45, and the arrangement must be such that the pump operator can easily tell whether water is coming from the air pipe or is wasting through the relief valve.

c. The cone should be piped to some point outside of the pump house where water can be wasted freely, the waste pipes being as below.

Size of Pump.	Diameter of Waste Pipe from Cone.
500-Gallon.	5 Inches.
750 "	6 "
1,000 "	7 "
1,500 "	8 "

The waste pipe can pass down to floor between the yokes at middle of pump. It should be piped in such a way that steam and gases from other drains or waste pipes will not work back through it, and, by being troublesome in the pump room, suggest the covering of the cone in any way, as it is desirable that the pump operator should *always* be able to see instantly any waste from the relief valve or air vent.

This cast-iron cone, connected to the safety valve and air vent, is included in price of pump, but the waste pipe beyond it is not.

45. *Air Valve.*

a. An air vent with a brass gate valve and brass pipe for connecting up must be provided and connected with delivery elbow and discharge cone.

b. The size of this air vent should be one inch for 500-gallon and 750-gallon pumps, and one and one-fourth inches for the 1000-gallon and 1500-gallon sizes.

c. The hand wheel of this valve must be marked as per sketch. The lettering must be very open, clear and distinct, not liable to be obstructed by grease and dirt, and of a permanent character.

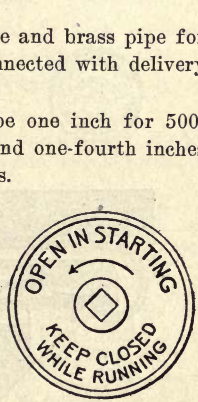


FIG. 13

The object of this valve is to reduce the pressure above force valves and secure a prompt riddance of all air that may come through the water cylinders when first starting up.

This valve, of course, should be closed when once pump is under way, to prevent waste of water.

46. *Priming.*

a. Each pump must be fitted with a set of brass priming pipes and valves, according to either one or the other of the following methods.

b. For 1,000 and 1,500 gallon pumps, the priming pipes must be $1\frac{1}{4}$ inch. For the 500 and 750 gallon pumps, the pipes must be 1 inch. Pump-makers are to furnish these pipes and the fittings called for below, and are to connect them up providing a 2-inch outlet, looking upwards, ready for the supply from the priming tank.

The pipe from the priming tank to this outlet should be at least 2-inch, and may be of iron, and is to be furnished

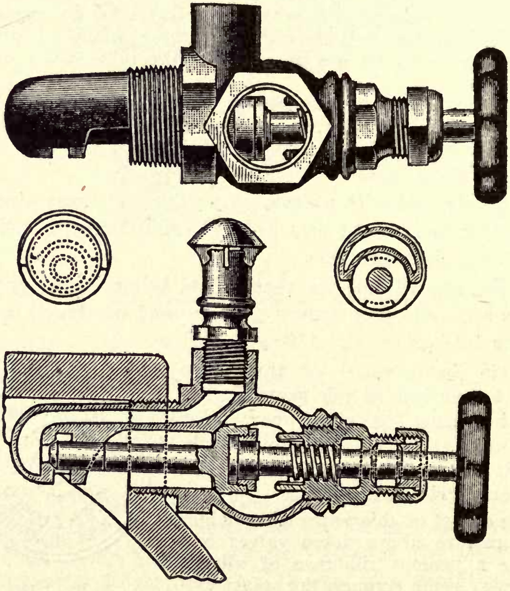


FIG. 14

by the purchaser. All parts furnished by the pump-maker are to be of brass, and are to be included in the price of the pump.

Controllable Valve Arrangement.

d. Four 2-seat controllable valves, one for each pulsation chamber, and of the general type illustrated in Fig. 14, must be provided. In these the inlet of water and the outlet of air are simultaneously opened and closed by the pump operator.

Objection has been raised to this double-seated valve from the possible difficulty of keeping both seats tight. If desired, the valve may be fitted with a flange instead of a screw connection, and the stem between the two seats somewhat enlarged and provided with a suitable spring, thus giving flexibility between the two seats and preventing all trouble from uneven wear.

d. The hand-wheel of each of these valves must be marked as per sketch, so that the pump operator may clearly understand their use. The lettering must be very open, clear and distinct, not liable to be obscured by grease and dirt, and of a permanent character.

FIG. 15

e. There must be provided and fitted to each combined valve a check and umbrella-top air vent, as shown in Fig. 16. This fitting must have a clear passageway through it, the full equivalent of a ½-inch bore.

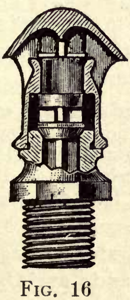


FIG. 16

The check-valve is to permit the outflow of air, but to prevent the influx when the plunger is sucking.

This method is preferred to the one using rubber priming checks, as now and then a rubber valve will stick on its seat and thus prevent priming of one of the chambers. In this arrangement the pump operator has absolute control over the priming water into each chamber. Another advantage is that the connection of the air-vent with the priming valve ensures that the air-vents will be opened; and further, by the vigorous spurting out of water

with the priming valve ensures that the air-vents will be as soon as the pump is primed, the pump operator is reminded that the priming valve should be closed.

Should the pump operator, however, through a mistaken idea of the proper method of operation, think that the priming should be continued until all air was exhausted from the suction pipe and the pump running in normal condition, there would be some by-passing between chambers, but as there is a free vent for the air, the main result would be simply to limit the amount of air exhausted per stroke, from the main suction, by the amount of water which entered a chamber in this way. The amount of water thus entering, however, would not be appreciably greater than that which would enter from the priming tank with the check-valve arrangement.

If, even in spite of the warning given by the spurting air-vents, the pump operator should neglect to close the priming valves when the pump was running normally, the priming tank would eventually be overflowed; but this would not be as serious as the drawing in of air from an exhausted priming tank, which would result with the check-valve method, were the main 2-inch valve similarly neglected.

Rubber Check Valves.

f. Four rubber check valves, one for each pulsation chamber, and similar to ordinary pump valves, must be provided. The chambers for these should preferably be made as a part of the pump cylinder, thus securing a compact arrangement.

Figure 12 shows this arrangement in outline.

g. The valve seat should have three ribs to the central hub, supporting the rubber valve. The net port area through the valve should be not less than 1½ square inches.

This valve seat should rest in an inverted position, and can be so fitted up as to be readily removed. The valve stems can be of the removable type screwing into the seat, but must be made long enough to receive a check nut on the opposite side of seat. This will effectually lock the stem in place.

h. Care must be taken to arrange the water passages through and about these priming checks, so as to avoid all

air pockets and so as to reduce to a minimum the possibility of the valves becoming choked up by refuse.

i. The valve seats, stems and all parts must be of composition and of strong, rugged design, so fitted up that there is the least chance for the rubber valves to stick, and with all parts securely put together the valves must be readily accessible.

j. The valve springs must have only sufficient strength to keep the valves on their seats, so that they will freely open even with the low head of priming water often existing.

k. There must be provided, and attached to the top of each plunger chamber, a brass check valve and air cock with umbrella top, as shown by Fig. 17. This cock and valve must have a clear passageway through them—the full equivalent of a ½-inch bore.

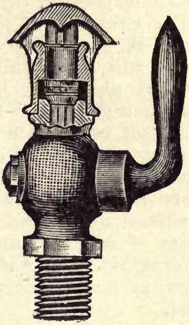


FIG. 17

The check-valve is to permit the outflow of air, but to prevent the influx when the plunger is sucking. Cocks with lever handles are used, as these show clearly whether they are open or shut.

l. There must also be provided a 2-inch brass gate valve for the general control of the water to the four check valves. The hand-wheel of this valve must be marked as per Fig. 15. The lettering must be very clear, open and distinct, not liable to be obscured by grease, and of a permanent character.

It is essential for a properly working pump that the main 2-inch priming valve should be closed as soon as the pump is primed. Otherwise, water will be drawn from the priming tank, lessening the lifting power of the pump through the main suction, and if this is continued the priming tank will often be exhausted and air drawn into the pump, interfering with its proper action. It is for this reason that the marking on the priming valve is required.

For all average situations, either method of priming permits of getting the pump under way in a very few minutes, but, for cases where the suction pipe is over 300 or 400 feet in length, or sometimes where the lift is over 18 feet, or where there is a combination of long length and lift within these limits, so much time is consumed in exhausting the air from the suction pipe that it becomes desirable to supplement this method.

For such situations, a steam ejector connected to the suction pipe near the pump is advised, and may be required in addition to the regular priming pipes and tank. The size of the ejector should be sufficient to exhaust the suction pipe within about three minutes. Such ejectors will be considered as extras not included in the ordinary pump fittings.

For cases where pump can only take its suction under a head, if absolutely certain that the level of the suction water will never fall below level of center of pump, these priming pipes may be omitted, but openings for them into the pump shell must be provided and capped or plugged.

A foot valve on a fire-pump suction is not advised except in very rare cases, as with a lift of 18 feet or a suction pipe 500 feet or more long. A foot valve is not needed when there is a good efficient set of priming arrangements as described above and it is commonly found it gives a false sense of security, and that with a fire-pump left standing several days the water will often be found to have leaked back, so that it is no better than if no foot valve had been used.

A foot valve must of necessity generally be located where it is inaccessible for quick repairs, and as they grow old, foot valves are often a source of trouble. Where a suction pipe is exposed even slightly to frost, a foot valve is specially objectionable.

A priming tank is provided by the purchaser in all cases where there is ever to be any lift on the suction. It is generally advised that this tank have a capacity of one-half of what the pump can throw at full speed in a minute. This means 250 gallons for a 500-gallon pump and 500 gallons for a 1,000-gallon pump, etc. It is the intention to make the pump a truly "independent source" of supply, therefore the need of a special priming tank.

Older Priming Arrangements.

The form of priming arrangement heretofore used, with metal check valves, one main 2-inch priming valve, and

1-inch priming pipes, separate controllable air cocks, may be retained on all pumps at present in service, and will be considered satisfactory, if kept in good order.

If in any case such checks give trouble the priming arrangement may be changed and valves like Fig. 14 or rubber checks as described in sections *f-j*, made up in detachable form,* may be put on if desired, where the connections on the pump permit them.

Where neither method is desired or where neither is feasible the faulty checks may be replaced by a special type such as are now made for this use, by the Locke Regulator Company, of Salem, Mass. These are 1-inch check valves, adapted to use a small disc of medium hard rubber, similar to a pump valve.

These fittings are very near the dimensions of the commercial check valve, so that with slight shortening of piping connections they will fit into the present arrangements, and give satisfaction.

47. *Drain Cocks.*

a. Five brass drain cocks, each with a lever handle and of ½-inch bore, are to be provided, and located one on each end of each water cylinder, and one above the upper valve deck.

Care should be taken to select a pattern of cock whose passageway is the practical equivalent of a ½-inch hole. Some patterns of ½-inch commercial cocks, although threaded for ½-inch pipe thread, have but a ¼-inch hole through them. Such are not acceptable.

TESTS FOR ACCEPTANCE.

48. *Test for Smoothness of Action.*

a. Provide outlets for the water; start the pump slowly, gradually open steam-throttle to bring the pump to full

*Such detachable rubber check valves are now made up in regular form by the George F. Blake Mfg. Co., East Cambridge, Mass.

speed. The pump should run smoothly at the rated full speed of 70 revolutions per minute (or 60 revolutions if a 1,500-gallon pump) with full length of stroke, and meanwhile maintain a water pressure of 100 pounds per square inch.

If the hose lines are short, or discharge is too free, partly close the water outlet valves, thus throwing an extra back pressure on the pump equivalent to that which would be produced through a greater length of hose.

During this trial it is preferable to discharge the water through lines of 2½-inch cotton rubber-lined hose, preferably each 150 feet long, each connected directly to the hose outlets on the pump, and each line having a 1⅛-inch smooth nozzle at its outer end. Two lines should be connected for a 500-gallon pump, three for a 750, and so on, having as many lines as rating of pump requires.

A hose line 150 feet long, with an inside surface of average smoothness, and with a 1⅛-inch nozzle attached, will require about 80 pounds pressure at the pump to discharge 250 gallons per minute, and the nozzle pressure will be about 45 pounds. Therefore, with lines attached as above, a pressure at the pump of about 80 pounds should represent a discharge about equal to the rated capacity of the pump, and would ordinarily correspond with the rated full speed revolutions.

If the pump runs smoothly under these conditions, it is well to open the throttle somewhat further, and bring the pressure at the pump up to 100 pounds. This will give a discharge of about 280 gallons per stream, or about 12 per cent. in excess of the rated capacity. The revolutions will, of course, correspondingly increase, and under all ordinary conditions a pump should run smoothly at this higher capacity, though a little more vibration and pounding would be expected than when running simply at its rated speed.

After cushion valves are adjusted there should be no noteworthy water hammer or valve-slam. Sometimes valve-slam is not the fault of the pump, but arises from an obstructed suction pipe. It is objectionable to doctor water hammer in a pump by snifting air into the suction, as this cuts down the efficiency and is a poor expedient.

The quietness of that part of the hose near the pump, or its freedom from rubbing back and forth crosswise an inch or more with each pulsation of the pump, is a good index

of the pump-maker's skill in securing uniform delivery. Bad pulsation quickly wears holes in the hose, and to reveal this is the object of testing *with hose connected directly to the pump.*

49. *Test of the Internal Friction.*

a. This is shown by the reading of steam gage compared with water pressure gage at air chamber.

Tests have generally run about as follows, for pumps running at full rated speed:

Size Gallons Per Minute Capacity.	Ratio of Steam Piston Area to Water Piston Area.	Water Pressure Lbs. Per Square Inches.	Steam Pressure Theoretically Necessary, Disregarding Friction.	Excess of Steam Pressure Needed to Overcome Friction, Back Pressure, Etc.	Actual Steam Pressure Found Necessary at the Pump.
500	4 Times	100	25	15	40
750	3 "	100	33	12	45
1,000	3 "	100	33	12	45
1,500	2¾ "	100	36.5	13.5	50

b. The steam pressure needed will vary slightly with the freedom of the exhaust pipe and with the tightness of the packings, etc., but a steam pressure of 45 pounds at the steam chest should suffice for 100 pounds water pressure on pump in proper adjustment.

50. *Test of Strength and Tightness.*

a. First, shut the main valve between the pump and the fire system lest a sprinkler head be burst, then shut all water outlets nearly, but not quite, tight, so pump will move very slowly. Screw safety valve down hard. Slowly and carefully admit steam pressure sufficient to give 240 pounds per square inch water pressure.

b. With this extreme pressure all joints should remain substantially tight, and the slow motion of the pump should be tolerably smooth and uniform. (The leakage of a few drops here and there and a little unsteadiness of motion are to be expected.)

c. If boiler pressure is above 85 pounds, the safety valve on pump should be attached and screwed down only enough to hold the required pressure. For with 100 pounds or more of steam the water pressure might be carried too high.

After completing the above test slack off on safety valve, setting it so that it will begin to open at about 100 pounds pressure

51. *Test of Capacity of Safety Valve.*

a. The relief vaive may next be testea by first adjusting it to pop at 100 pounds, then shut the main outlet to pump, and then shut the hose gates one by one, and thus force all the discharge through the relief valve, meanwhile opening steam throttle, so as to run pump *first at two-thirds speed or about* 50 *revolutions per minute,* and finally at full speed (70 revolutions). The safety valve (relief valve) should carry all this and not let the pressure rise above 125 pounds.

The pressure in a quick-moving fire pump necessarily fluctuates 5 to 15 pounds at different points in stroke, and an air chamber of reasonable size cannot wholly remove this. Therefore, the safety valve must be set at about 15 pounds higher than the intended average working pressure; otherwise it will get to jumping with almost every stroke.

52. *Test of Internal Leakage or Slip.*

a. Set safety valves at 115 lbs., shut all water outlets, admit steam enough to give 100 pounds water pressure, then pump will move very slowly under the influence of the leakage past plungers, about one revolution of pump per minute shows a proper accuracy of fit. Anywhere from $\frac{1}{3}$ to 2 revolutions per minute is satisfactory.

Too tight a fit is bad, as if not exceedingly uniform it induces scoring or fretting of the metals. Moreover, should

pump happen to be run dry for a few minutes before catching its suction a slight warming and expansion of the plunger may cause it to stick and fret.

53. *Test With Maximum Working Pressure.*

a. For this, alternately shut down the main outlet gate and adjust the hand-wheel of the safety valve, and open up on the throttle as may be required, running pump at say, one-half speed (or, in experienced hands, at full rated speed), and note the greatest water pressure which the full boiler pressure (unless boiler pressure is above 85 lbs.) will yield with pump at full speed.

Sometimes it may be necessary to force water through very long lines of hose, or to an unusual height.

Steam fire engines are not infrequently called on to give 200 pounds per square inch water pressure.

To test short hose lines with anywhere near so high a pump pressure is dangerous, lest nozzle kick and pull itself away from the man holding it and thresh around; but the ability of the pump may be tested by putting this high pressure delivery mainly through the safety valve, or in part through the partially closed main outlet gate.

It is not advisable to carry this water pressure above 200 pounds in this test at the factory, although in the shop test the water pressure is carried to 240 pounds, and engine driver should stand with his hand on the throttle.

54. *Test for Maximum Delivery.*

a. This can best be tried by adding one, or, in some cases, two more streams than the pump is rated to deliver by attaching the extra lines of hose to some hydrant near, and then speed up the pump gradually, to see how fast it may be run before violent pounding or slamming of valves begins.

Sometimes the increased delivery can be drawn off through an open hydrant-butt meanwhile holding sufficient back pressure to show 100 pounds on the water gage by partly closing the discharge valve.

The engine driver should stand with his hand on or near the throttle when thus speeding the pump.

It is all right to run a fire pump up to the utmost speed possible before water hammer begins, and very often a pump, while new and if favorably set up, can deliver 25 to 50 per cent. more than rated capacity; nevertheless, although expert treatment can force 1,000 gallons from a 16x9x12 pump, we can rate it as only a 750-gallon pump. *There must be some margin to allow for wear and for the possible absence of the expert at time of fire.*

The main points of difference between the "National Standard" and the "Trade Pump" are:

Brass plungers instead of cast iron plungers.

Wrought iron side levers instead of cast iron.

Bronze piston rods and valve rods instead of iron or steel.

Pump has brass-lined stuffing boxes instead of cast iron.

Rock shafts are brass bushed.

Area of water valves is 25 to 50 per cent. greater.

Steam and exhaust passages 20 to 50 per cent. greater.

Suction pipe connections two to four inches greater diameter.

Cushion valves better arranged.

Air chamber is made much larger.

Shells and bolting are warranted especially strong.

The following necessary fittings are included in the price, and regularly furnished as a part of this pump, viz.:

A capacity plate.

A stroke gage.

A vacuum chamber.

Two best quality pressure gages.

A water relief valve of large capacity.

A cast iron relief valve discharge cone.

A set of brass priming pipes and special priming valves.

From two to six hose valves.

A sight feed cylinder lubricator connected above throttle.

A one-pint hand oil pump connected below throttle.

INDEX TO PUMP SPECIFICATIONS.

For amendments to National Board Rules adopted by the National Fire Protection Association, since the foregoing rules were promulgated, see page 360.

STEAM PUMP TABLES.

The following data, including capacities, etc., are from catalogues furnished by the makers:

WHEELER UNDERWRITER FIRE PUMP.

Formerly known as the Barr Underwriter Pump.

Manufactured by C. H. Wheeler Manufacturing Co., Philadelphia, Pa.

Maker's Rated Capacity	Diam. Steam Cylinder	Diam. Water Cylinder	Length of Stroke	Size of Pipes Steam	Exhaust	Suct.	Disch.
500	14	$7\frac{1}{4}$	12	3	4	8	6
750	16	9	12	$3\frac{1}{2}$	4	10	7
1000	18	10	12	4	5	12	8
1500	20	12	16	5	6	14	10

FAIRBANKS-MORSE UNDERWRITER FIRE PUMP.

Manufactured by Fairbanks-Morse & Co., Chicago, Ill.

500	14	7	12	3	4	8	6
750	16	9	12	$3\frac{1}{2}$	4	10	7
1000	18	10	12	4	5	12	8
1500	20	12	16	5	6	14	10

FAIRBANKS-MORSE DUPLEX FIRE PUMP.

204– 306	10	5	12	2	$2\frac{1}{2}$	6	5
294– 441	12	6	12	$2\frac{1}{2}$	3	6	5
400– 600	14	7	12	$2\frac{1}{2}$	3	8	6
522– 783	16	8	12	$2\frac{1}{2}$	3	8	6
660– 990	16	8	12	$2\frac{1}{2}$	3	8	6
816–1224	18	10	12	3	$3\frac{1}{2}$	10	8
816–1224	18	10	18	3	$3\frac{1}{2}$	10	8
816–1224	20	10	18	3	$3\frac{1}{2}$	10	8
1174–1761	20	12	18	4	5	10	8

GARDNER REGULAR FIRE PUMP.

Manufactured by the Gardner Governor Co., Quincy, Ill.

Maker's Rated Capacity	Diam. Steam Cylinder	Diam. Water Cylinder	Length of Stroke	Size of Pipes Steam	Exhaust	Suct.	Disch.
250	10	5	10	2	$2\frac{1}{2}$	5	4
350	12	6	12	$2\frac{1}{2}$	3	7	6
500	14	7	12	$2\frac{1}{2}$	3	7	6
750	16	8	12	$2\frac{1}{2}$	3	7	6
900	16	9	12	$2\frac{1}{2}$	3	8	7
1000	18	9	12	3	4	8	7
1200	18	10	12	3	4	10	8
1200	20	10	12	4	5	10	8
1500	20	12	12	4	4	12	8

GARDNER STANDARD FIRE PUMP.

Maker's Rated Capacity	Diam. Steam Cylinder	Diam. Water Cylinder	Length of Stroke	Size of Pipes Steam	Exhaust	Suct.	Disch.	Handbook Rated Capacity
550	12	7	12	$2\frac{1}{2}$	3	7	6	....
550	14	7	12	$2\frac{1}{2}$	3	7	6	....
700	14	8	12	$2\frac{1}{2}$	3	7	6	....
750	16	8	12	$2\frac{1}{2}$	3	8	6	....
900	16	9	12	3	4	8	7	....
900	18	9	12	$3\frac{1}{2}$	4	8	7	....
1200	18	10	12	$3\frac{1}{2}$	4	10	8	....
1200	20	10	12	$3\frac{1}{2}$	4	10	8	....

SMITH-VAILE UNDERWRITER FIRE PUMP.

Manufactured by The Platt Iron Works Co., Dayton, Ohio.

320	12	6	12	$2\frac{1}{2}$	3	6	5	359
500	14	7	12	3	4	8	6	484
750	16	9	12	$3\frac{1}{2}$	4	10	7	807
1000	18	10	12	4	5	12	8	990
1000	20	12	16	5	6	14	10	1650

THE SNIDER-HUGHES DUPLEX PUMP.

Manufactured by The Snider-Hughes Co., Cleveland, Ohio.

Maker's Rated Capacity	Diam. Steam Cylinder	Diam. Water Cylinder	Length of Stroke	Size of Pipes				Handbook Rated Capacity
				Steam	Exhaust	Suct.	Disch.	
200	8	5	12	1½	2	4	3	....
200	10	5	12	2	2½	4	3	....
292	10	6	12	2	2½	5	4	....
292	12	6	12	2	2½	5	4	....
398	10	7	12	2	2½	6	5	....
398	12	7	12	2	2½	6	5	....
398	14	7	12	2½	3	6	5	....
550	12	8½	12	2	2½	8	6	....
550	14	8½	12	2½	3	8	6	....
550	16	8½	12	3	3½	8	6	....
816	14	10	12	2½	3	10	8	....
816	16	10	12	3	3½	10	8	....
816	18	10	12	3½	4	10	8	....
1174	16	12	12	3	3½	12	10	....
1174	18	12	12	3½	4	12	10	....
1550	18	14	12	3½	4	12	10	....

SNOW UNDERWRITER FIRE PUMP.

Manufactured by the Snow Steam Pump Works, Buffalo, N. Y.

Maker's Rated Capacity	Diam. Steam Cylinder	Diam. Water Cylinder	Length of Stroke	Size of Pipes			
				Steam	Exhaust	Suct.	Disch.
360	12	6	12	2½	3	6	5
520	14	7¼	12	3	4	8	6
800	16	9	12	3½	4	10	7
1000	18	10	12	4	5	12	8
1650	20	12	16	5	6	14	10

BLAKE UNDERWRITER FIRE PUMP.

Manufactured by the Geo. F. Blake Manufacturing Company.

500	14	7¼	12	3	4	8	6
750	16	9	12	3½	4	10	8
1000	18	10	12	4	5	12	8
1500	20	12	16	5	6	14	10

SNOW DUPLEX FIRE PUMP.

Maker's Rated Capacity	Diam. Steam Cylinder	Diam. Water Cylinder	Length of Stroke	Size of Pipes Steam	Exhaust	Suct.	Disch.
115– 167	8	4	10	1½	2	4	3
179– 261	10	5	10	2	2½	5	4
196– 294	10	5	12	2	2½	5	4
196– 294	12	5	12	2½	3	5	4
282– 423	12	6	12	2½	3	5	4
282– 423	14	6	12	2½	3	5	4
384– 576	14	7	12	2½	3	6	5
384– 576	16	7	12	3	4	6	5
500– 750	16	8	12	3	4	8	6
565– 847	18	8½	12	3	4	8	6
633– 949	18	9	12	3	4	8	7
633– 949	20	9	12	4	5	8	7
782–1173	18	10	12	3	4	8	7
782–1173	20	10	12	4	5	8	7
1122–1683	20	12	12	4	5	10	8

HENRY R. WORTHINGTON UNDERWRITER FIRE PUMP.

Manufactured by Henry R. Worthington, New York, N. Y.

500	14	7¼	12	3	4	8	6
750	16	9	12	3½	4	10	8
1000	18	10	12	4	5	12	8
1500	20	12	16	5	6	14	10

RULES AND REQUIREMENTS

For the Construction and Installation of

STEAM PUMP GOVERNORS AND AUXILIARY PUMPS.

NOTE.—Pages 170 to 177 are a reprint of the Rules and Requirements of the National Board of Fire Underwriters (1904.)

Automatically controlled pumps are not advised as a primary water supply wherever it is possible to get a satisfactory gravity supply.

Whenever it is necessary to put in an automatically controlled pump an auxiliary pump should always be used to maintain the pressure and supply leakage.

The reason for the auxiliary pump is first that it permits the large pump to remain at rest, thus saving excessive wear, and, second, it is much more economical of steam. Excessive wear is objectionable, as it means a large slip, thus reducing the capacity of the pump, and further, because the wear under those conditions of running is apt to be in the middle of the travel of the rods and plungers, with the danger that the rods will stick in the stuffing boxes when the pump is put up to full stroke.

Construction of the Governor.

Successful governors vary too greatly in type to admit of uniform mechanical construction. The following requirements cover general points necessary in governors of all types. A searching test under practical working conditions must be the main criterion for acceptance and for the listing of a governor as an approved device.

1. The governor to be controlled by the water pressure in the fire system.

2. To be adjustable to maintain any desired pressure between 75 and 125 lbs., using steam at any pressure from 50 to 150 lbs.

3. To be capable of governing the pump from slow speed to full speed without more than about 5 lbs. variation above or below the intended water pressure.

4. To not show distress under steam pressure at 200 lbs.

5. To be capable of enduring 240 lbs. water pressure without injury.

6. Must be rustproofed throughout by making all working parts of brass, bronze, or other suitable non-corrosive material.

7. It is preferable that valve close by abutment contact on valve seat.

8. Valve and valve seat must be removable without removing governor from piping.

9. Maximum working lift of valve must afford practically same steam passage area as that of the steam pipe controlled by governor.

10. To have screwed connections for attachment to ordinary pipe fittings.

11. To have no internal stuffing box or gland.

12. Should preferably admit of full manual movement on inspection, as a proof of working freedom of parts.

13. Should have a tendency to increase rather than decrease the water pressure as the speed of the pump increases.

14. Should respond slowly to any sudden lowering of water pressure and thus start the pump gradually.

15. Concealed mechanism should be kept at a minimum.

16. Should avoid internal steam joints capable of leaking and passing unregulated steam to the pump.

Auxiliary Pumps.

1. Auxiliary pump should be of duplex type, brass fitted and with packed pistons or exterior packed plungers.

2. The ratio of steam and water piston areas should be about the same as for the main pump.

For Plan A (see cuts) it is advised that auxiliary pump be about a 4½"x2"x4". For Plans B and C a larger water cylinder is generally necessary to get the lifting power needed and about a 5¼"x3½"x5" pump is advised. These pumps are large enough to take care of the leaks and wastes in the ordinary fire system.

In special cases where a larger amount of water must be more or less continuously supplied from a fire system, the auxiliary pump must be larger and may be of any size desired.

The auxiliary pump is of value to keep the main fire pump primed, as well as to maintain the pressure and waste in the fire system.

Installation of Governors and Auxiliary Pumps.

1. Auxiliary pump and connections are recommended to be arranged as shown in Plan A or as in Plan B for lifts up to 12 or 15 feet. For higher lifts Plan C is suggested. (See cuts.)

This applies to the scheme of connections and number and location of valves, but not to the exact location of the auxiliary pump.

With plan A the question has been raised that the main pump may not be primed at all times. This method has, however, been considerably used and has so far given satisfaction under all conditions.

Plan B insures that main pump will always be primed, but can generally not be successfully maintained unless the auxiliary pump has a considerable lifting ability.

For lifts over 12 to 15 feet it may be difficult to make an auxiliary pump as per plan B work satisfactorily, and the possible danger from imperfect priming in Plan A becomes greater. The arrangement of Plan C insures that pump and suction pipe are solid full of water at all times and is therefore considered safer. A metal seat foot valve is required, as a soft seat might cause sticking after long subjection to the auxiliary pump pressure.

2. The main pump and the auxiliary pump to have separate governors made entirely independent by a valve on the water connection of each.

3. The size of governors for the main pump should be as follows:

For 500-gallon pump, $1\frac{1}{4}''$ governor.

For 700-gallon pump, $1\frac{1}{2}''$ governor.

For 1,000-gallon pump, $2''$ governor (possibly $1\frac{1}{2}''$).

For 1,500-gallon pump, $2''$ governor.

4. The governor for the auxiliary pump should be $\frac{3}{4}''$ connected into a $\frac{1}{2}''$ steam pipe.

A pipe larger than $\frac{1}{2}''$ is undesirable, as it would permit excessive racing of the small pump if the pressure in the main system were low. A $\frac{3}{4}''$ governor is required to get the working parts large enough to be reliable.

5. The auxiliary pump should have a separate exhaust entirely independent of the large pump.

If the auxiliary pump exhaust is connected into the exhaust of the main pump there is danger of water collecting in the large pump pipe and making trouble.

6. The water pressure pipe controlling the governors must be of brass. It must connect beyond the main pump discharge check and must have control gates as called for in Art. 2.

7. Lubricant to be applied so as not to pass through governors before entering pumps, unless manufacturers specify otherwise.

8. The governor for large pump to be installed on usual "three valve" by-pass arrangement of steam piping.

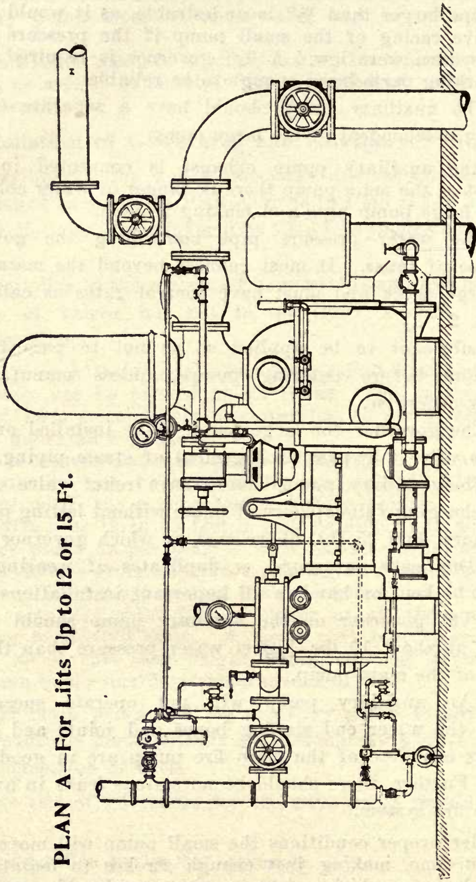
9. The auxiliary pump should have relief valve capable of discharging full capacity of pump without letting pressure rise more than 25 lbs. above that at which governor is set.

10. Duplicate governors, or duplicates of wearing parts should be kept on hand in all important installations.

11. The governor on the auxiliary pump should usually be set at about 10 lbs. higher water pressure than the governor of the main pump.

12. An auxiliary pump will not operate successfully unless the water end stuffing boxes and joints and suction fittings complete of the main fire pump are in good condition. Further, there should be no serious leaks in any part of the fire system.

Under proper conditions the small pump will move slowly all the time, making just enough strokes to maintain the small leakage which exists in any considerable equipment. The large pump will remain quiet until there is a demand for water by sprinklers or hose streams.



PLAN A—For Lifts Up to 12 or 15 Ft.

PLAN A—For Lifts Up to 12 or 15 Feet.

The auxiliary pump is placed under the main pump at one side.

GG—Automatic governors.

RV—Relief valve on auxiliary pump.

H—Connection to hose valves.

T—Steam trap.

Sight feed lubricators are shown for both the large and the small pump.

A forced feed lubricator could be used as shown in Plan C, if desired.

PLAN B—For Lifts Up to 12 or 15 Feet.

The auxiliary pump is shown on a shelf on the side wall of the Pump House. If desired the auxiliary pump can be placed on brackets on top of the main pump. If on the wall the auxiliary pump should be set high enough so that men can walk under the steam and suction pipe without stooping. The check on main pump discharge is shown just outside of the pump house in a brick well.

GG—Pump governors.

RV—Relief valve on auxiliary pump.

T—Steam trap.

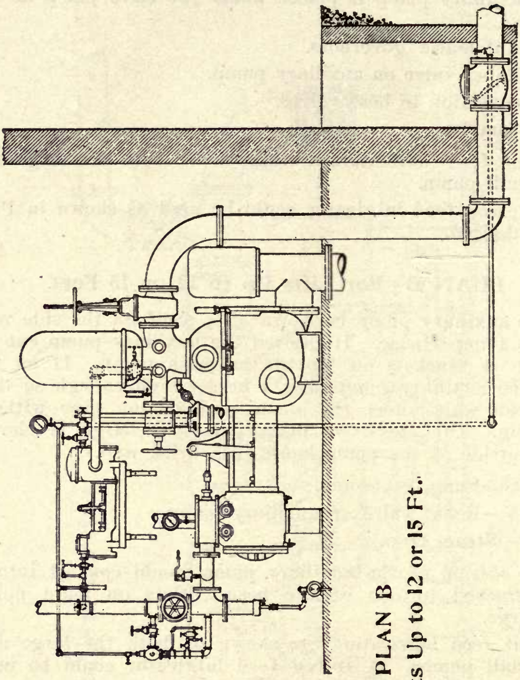
The suction of the auxiliary pump would connect into a tee attached to one of the hose outlets on main pump discharge.

Sight feed lubricators are shown on both the large and the small pumps. A forced feed lubricator could be used as shown in Plan C, if desired.

PLAN C—For Lifts Over 15 Feet, but Suitable for Use with Lesser Lifts.

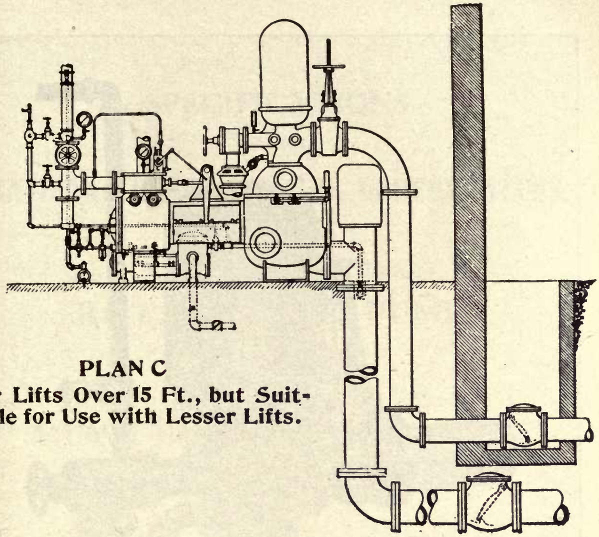
The auxiliary pump is shown on the floor of pump house over against one of the side walls. The suction pipe S for the auxiliary pump is carried independently of the suction of the main pump to some reliable water supply, either that from which the main pump draws or from any other source.

A check valve should be provided at the end of this pipe to act as a foot valve.



PLAN B
For Lifts Up to 12 or 15 Ft.

The discharge of the auxiliary pump is carried into the suction of the large pump and the large pump suction is provided with a metal seat for valve. With this arrangement the auxiliary pump keeps all connections on the large pump full of water.



PLAN C
For Lifts Over 15 Ft., but Suitable for Use with Lesser Lifts.

A foot valve with metal seat is required, as there would be danger of a soft seat sticking due to the constant pressure maintained by the small pump.

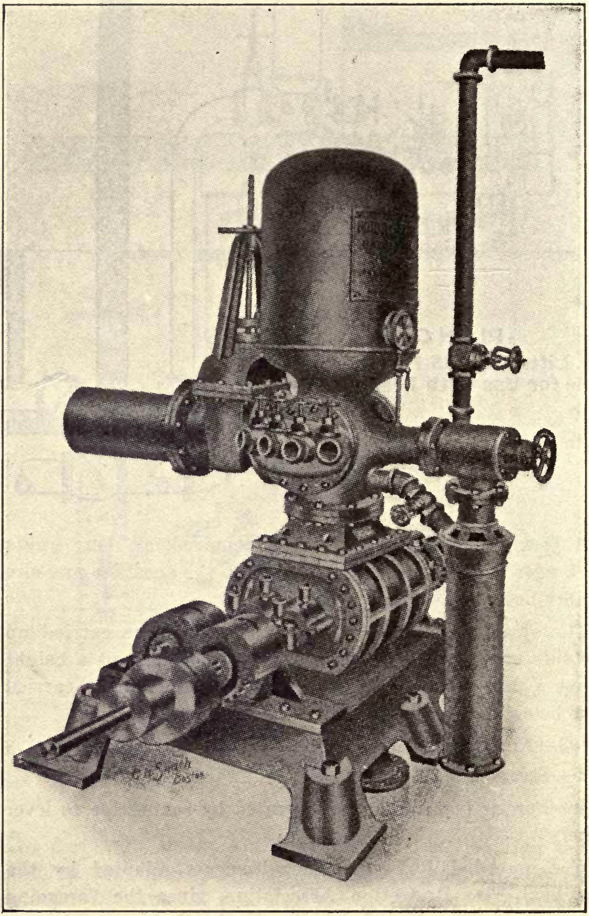
The steam and pressure pipe connections are carried up the side wall and thence over to the main pump at a height above a man's head. The discharge pipe should be carried just below the floor in a trench covered with a plate.

GG—Automatic governors.

T—Steam trap.

L—Forced feed lubricator operated by connection to lever arm.

For amended Rules and Requirements adopted by the National Fire Protection Association, since the foregoing rules were promulgated by the National Board of Fire Underwriters, see page 363.



National Standard Rotary Fire Pump.

SPECIFICATIONS

OF THE

NATIONAL BOARD OF FIRE UNDERWRITERS

FOR THE MANUFACTURE OF

ROTARY FIRE PUMPS

AS RECOMMENDED BY THE

NATIONAL FIRE PROTECTION ASSOCIATION.

EDITION OF 1905.

UNIFORM REQUIREMENTS.

These specifications for Rotary Fire Pumps are now used throughout the whole country, having been agreed upon in joint conference by representatives of the different organizations interested in this class of work. They will be known as "The National Standard" and have been, up to this time, adopted by the following Associations:

Associated Factory Mutual Fire Insurance Companies.
National Board of Fire Underwriters.
National Fire Protection Association.

NOTE.—Pages 178 to 215 are a reprint of the pamphlet on Rotary Fire Pumps of the National Board of Fire Underwriters.

RULES AND REQUIREMENTS FOR ROTARY FIRE PUMPS.

These specifications have been drawn up with the idea of improving the present type of rotary pump as far as possible without requiring an entirely new line of patterns, as it is believed that centrifugal pumps are likely to replace rotary pumps for fire purposes to a greater or less extent.

Many of the rotary pumps now in use have too small pipe connections for good results, sticking often occurs after disuse (due to rusting), there are weak details in construction of some makes, relief valves and hose connections are frequently absent; so that some general improvements are essential if rotary pumps are to be considered satisfactory fire pumps and comparable with steam pumps built in accordance with the National Standard.

Pumps built according to these specifications will differ from the present types principally in the following points:

1. Larger water passages at the suction and discharge ends.

2. Less chance of corrosion, the body and cams being entirely of bronze.

3. The introduction of a special discharge casting similar to that used with steam pumps and including an air chamber, hose connections, relief valve, starting valve, priming pipe, capacity plate, pressure gages, etc.

THE PUMP.

1. *Workmanship.*

a. The general character and accuracy of foundry and machine work must be in line with good machine shop practice.

This refers to strength of detail, accuracy of foundry work, accuracy of alignment, accuracy of fits, etc., and does not apply particularly to exterior finish.

2. *Type.*

a. Pump to be of the double rotary type with two main shafts.

3. *Capacity.*

a. Pumps to be classed and rated in the following sizes, and to discharge these quantities under 100 lbs. pressure at pump:

Gallons per minute.	No. of $1\frac{1}{8}''$ hose streams.	Speed.
500	2	250 to 300
750	3	
1000	4	(Preferably an even number, such as 250, 275 or 300.)
1500	6	

Manufacturers may use present patterns, taking the smallest pump that will give the necessary discharge and rating it at one of the above figures.

b. Pump must discharge at least 20% in excess of its rated capacity when new.

4. *Power.*

a. General practice shows that as ordinarily constructed and connected with friction gears, rotary pumps require about 30 H. P. for every 250 gallons delivered, with 100 lbs. pressure maintained at pump. Where driven by spur gear, considerably less power may be required. It is desirable that pumps be so constructed that they will be economical of power.

5. *Capacity Plate.*

a. Pump to have a capacity plate securely fastened to air chamber, containing the following information:

....*

ROTARY FIRE PUMP.

NATIONAL STANDARD.

CAPACITY.

750 Gallons per Minute, or
3 Good $1\frac{1}{8}$-inch Smooth Nozzle
Fire Streams.

3 Gallons per Revolution.
Full Speed 250 Revolutions per Minute.
Never fail to have ample power to drive
pump at full speed.

*Name of pump manufacturer to be placed here.

This plate must have an area of not less than one square foot and must be of an alloy at least $\frac{2}{3}$ aluminum, the remainder being zinc. The letters must be at least $\frac{1}{2}$ inch in height, plain and distinct, with their surface raised on a black background and buffed off to a smooth finish.

b. A small plate of composition giving size of pump, shop number and name of shop in which pump was built must also be attached to or cast onto the pump in some conspicuous place.

6. *Strength.*

a. The maker must warrant the pump to safely withstand and be substantially tight under 240 lbs. pressure.

b. Bolts may be of steel, iron or Tobin bronze and the bolting of all parts subject to water pressure, to be of such strength that the maximum stress at bottom of screw thread will not exceed 10,000 lbs. per square inch (disregarding

for the moment the initial stress due to setting up nuts) for a water pressure of 200 lbs. per square inch, computed on an area out to center line of bolts.

c. No steel or iron stud or bolt smaller than $\frac{3}{4}$ inch and no Tobin bronze smaller than $\frac{5}{8}$ inch should be used to assemble parts subject to strain of water pressure.

Although these pumps are not expected to be designed for a regular working pressure of 240 pounds, it is expected that bolts, shells, etc., will be figured to stand this comparatively quiet, temporary high pressure, exclusive of further allowance for initial strain due to setting up of bolts, with a factor of safety of at least four.

d. Pump must be able to run safe at 25% excess speed with 100 lbs. pressure, or at $\frac{2}{3}$ rated speed with 150 lbs. pressure for two hours without overheating or requiring tigthening of bolts.

7. *Shop Inspection.*

a. A systematic shop inspection must be given to each pump to ensure complete workmanship and to prevent the use of defective parts, improper materials, or the careless leaving of foreign matter in any part of the pump.

8. *Body of Pump.*

a. The cylindrical portions and the ends to be of cast bronze at least $\frac{5}{8}$ inches thick for the smallest size when finished. All sizes to be of sufficient thickness to withstand the pressure specified in section No. 6.

It is generally believed that careful ribbing is preferable to excessive thickness in metal.

In pumps where cams or pistons have a bearing adjustable abutments only, it may be sufficient to have the body of pump of iron and the abutments of bronze.

b. These parts to be hard and close grained with metal so distributed as to ensure sound casting and freedom from shrink cracks.

c. Ends of pump to have arrows cast on the metal, showing direction which shaft is designed to turn. Arrows to be at least 4 inches long and raised at least $\frac{1}{8}''$ above surface.

9. *Bed Plate.*

a. Pump to have a heavy bed plate to which bearings and pump must be firmly secured. Bed plate to have four and preferably six bolt holes for securing it to foundation. No bolt to be less than $\frac{3}{4}$ inch in diameter.

10. *Cams.*

a. To be cast in one piece of hard, close-grained bronze; to be secured to shaft by standard key running the entire width of cam. Blades or buckets to be designed so as to give ample strength. Bronze packing or adjustable slides are not advised, but will be allowed if found satisfactory after special examination. The fit of cams to be as close as practicable, but not so close as to allow for any chance of sticking.

b. Cams to be so designed that pump will run smoothly without pounding. This frequently requires properly designed cavities in pump ends to prevent undue pressure from water which may be pocketed by cams.

11. *Shafts.*

a. To be of best forged steel of ample strength. Shafts to be bronze covered from ends of cam to outside of stuffing boxes. The bronze cover must fit the shaft closely and must be forced on making a tight joint with the cam.

12. *Bearings.*

a. Main bearings to be lined with best babbitt and to be located as near ends of pump as possible. Babbitt to be hammered in and then bored out to the necessary size. Length of main bearings to be at least three times the diameter of shaft.

13. *Pipe Sizes.*

a. Inlet and discharge openings to be of not less than the following diameter:

Size.	Suction.	Discharge.
500 gals.	6″	6″
750 gals.	8″	8″
1000 gals.	8″	8″
1500 gals.	10″	10″

b. Suction pipe to be of the same size as flange opening except that when pump takes suction under lift and where suction is over 15 feet long or has over two elbows, the suction pipe must be of the following sizes: 500 gal., 8″; 750 gal., 10″; 1000 gal., 10″; 1500 gal., 12″. The increase in size to be made by a fitting of long taper.

c. Standard flanges and standard bolt layouts as adopted by the Master Steam Fitters, July 18th, 1894, must be used on all the above pipe connections, as per table given below:

SCHEDULE OF STANDARD FLANGES.

Size of Pipe x Diam. of Flange.	Diameter of Bolt Circle.	Number of Bolts.	Size of Bolts.	Flange Thickness at Edge.
Inches.	Inches.		Inches.	Inches.
3 x 7½	6	4	⅝ x 2½	13/16
3½ x 8½	7	4	⅝ x 2½	7/8
4 x 9	7½	4	¾ x 2¾	15/16
4½ x 9¼	7¾	8	¾ x 3	15/16
5 x 10	8½	8	¾ x 3	15/16
6 x 11	9½	8	¾ x 3	1
7 x 12½	10¾	8	¾ x 3¼	1 1/16
8 x 13½	11¾	8	¾ x 3½	1 1/8
9 x 15	13¼	12	¾ x 3½	1 1/8
10 x 16	14¼	12	⅞ x 3⅝	1 3/16
12 x 19	17	12	⅞ x 3¾	1 1/4
14 x 21	18¾	12	1 x 4¼	1 3/8

14. *Gears.*

a. Pump to have a pair of outside cut gears at each end of shafts with an outside bearing for each gear. Gears to be of forged steel or iron, steel casting or cast iron, and designed to transmit the necessary power with a liberal factor of safety. Gears to be located close to main bearings, and to be protected by cast iron shields securely fastened in place.

15. *Couplings.*

a. One shaft to be fitted with a machine faced jaw coupling of ample strength.

16. *Discharge Casting.*

a. Pump to have a discharge casting to which is attached main discharge pipe, hose connections, relief valve, starting valve, priming pipe and air chamber. It is advised that air chamber be part of same casting, but if this is not done the air chamber to be bolted to the upper side of the discharge casting.

These outlets to be the following sizes:

Size of Pump—	500	750	1000	1500
On two opposite sides for Hose Connection	5″	6″	7″	8″
For Main Discharge	6″	8″	8″	10″
For Relief Valve	3″	3½″	4″	5″
Priming Connections	2″	2″	2″	2″
Starting Valve	2″	2½″	2½″	3″
Air Chamber Neck	5″	6″	6″	8″

b. All of the above outlets except those for starting valve and priming connection to be flanged. Standard flanges and standard bolt layouts as given in Section No. 13 to be used. Blank flange to be supplied for hose outlet that is not used.

17. *Hose Connections.*

a. A casting to be furnished with flange connection drilled to fit one of the outlets of the discharge casting as mentioned in Section No. 16. This casting to be fitted with two or more hose connections according to the capacity of the pump, each hose outlet being fitted with an approved gate valve.

Size of Pump.	No. of Connections.
500 gals.	2
750 gals.	3
1000 gals.	4
1500 gals.	6

b. Where hose cannot be carried direct to pump the hose connection casting to be placed at any convenient point and connected to pump by pipe of same size as hose outlet connection (see Section 16).

18. *Air Chamber.*

a. To be properly designed to provide a smooth, even discharge. Capacity to be at least two gallons for every hundred gallon capacity of pump. To be of as little height as feasible. Where not a part of discharge casting to have a flanged connection arranged to fit the top of discharge casting (see schedule of standard flanges). To be tested under 400 lbs. and to be painted inside and out.

19. *Safety Valve.*

a. A spring pattern safety or relief valve of any make agreed upon in writing with the Underwriters having jurisdiction is to be included in the price. To be attached to each pump, extending horizontally so that its hand-wheel for regulating pressure is within easy reach. This hand-wheel must be marked very conspicuously with the word "open" and an arrow showing in which direction the valve is opened.

b. This valve is to be set ordinarily at a working pressure

of 100 lbs. to the square inch, and to be of such capacity that when set at 100 lbs. it can pass all the water discharged by the pump at full speed, at a pump pressure not exceeding 125 lbs. per square inch.

Size of Pump.	Size of Relief Valve.
500 gal.	3″
750 gal.	3½″
1000 gal.	4″
1500 gal.	5″

c. Where relief valve does not discharge into an open pipe in plain sight near pump it should discharge with a cone or funnel secured to outlet of valve. This cone should be so constructed that pump operator can easily see any water wasting through relief valve, and its passages should be of such design and size as to avoid splashing water into the pump room. To be piped off to some point outside of pump house where water can be wasted freely.

d. When the supply of water is limited, as from a special suction reservoir or cistern, the waste pipe must drain into such reservoir or cistern entering as far from the pump suction as is necessary to prevent the pump from draughting air which may be carried down into the cistern by the discharge from the waste pipe.

e. Size of waste pipes to be as follows:

Size of Pump.	Size of Waste Pipe.
500 gal.	5″
750 gal.	6″
1000 gal.	7″
1500 gal.	8″

f. Relief valve to be so attached to delivery elbow and discharge cone by flange connections as to permit of its ready removal for repairs without disturbing the waste piping.

20. *Starting Valve.*

a. Pump to have a starting valve of a size determined by the following table:

Size of Pump.	Size of Starting Valve and Pipe.
500 gal.	2″
750 gal.	2½″
1000 gal.	2½″
1500 gal.	3″

b. Valve to be of approved indicator pattern, to connect with discharge casting at some convenient point, preferably at relief valve, and to be arranged so that discharge may be plainly seen by the man in charge. In locations where a discharge cone is needed for relief valve, the starting valve pipe should be run into this cone.

The object of this valve is to afford a ready relief for air in the discharge pipe and also to give a means of regulating the pressure with pump running at full speed.

21. *Pressure Gage.*

a. A pressure gage of the Lane double tube spring pattern with 5″ case, must be provided with the pump, and connected to air chamber by a ½″ cock with lever handle, as shown in sketch.

The dial of this gage should be scaled to indicate pressures up to 240 lbs. and be marked "WATER."

22. *Oil and Grease Cups.*

a. Each of the babbitted bearings and each of the bronze bearings to have a compression grease cup. Top plate of pump to have four oil holes at least ¼ inch in diameter fitted with brass thumb screw plugs.

CONNECTION AND SETTING.

23. *Driving Gearing.*

a. The best method of driving any rotary pump depends

largely upon circumstances and no definite rules governing this can be laid down. The following methods are recommended in the order given:

1—Direct from independent source of power.

2—Spur gearing from independent source of power. In this case the pump should be kept in gear at all times.

3—Spur gearing from main shaft with a satisfactory clutch. Clutch should be operated from pump room and only such clutches should be used as are approved by the Underwriters having jurdisdiction.

4—Grooved friction gearing from main shaft. Gears to comply with rules given in Section No. 24.

24. *Grooved Friction Gears.*

a. There must be a pair of friction driving gears, one being fastened direct to driving shaft and the other connected to pump shaft through jaw coupling. There should be enough play in this coupling to allow gear to slide a trifle and thus mesh properly with driving gear.

b. Friction gears to have bearings at both ends. Length of bearings to be at least three times the diameter of shaft.

c. Friction gears to be properly designed to transmit the necessary power and give the required speed with a surface velocity that is not excessive.

d. Grooves to be recessed at bottom and to be properly designed to grip tightly without undue slip.

e. Gears to be set on rugged framework amply strong to sustain any strain that is liable to be put upon it. Care should be taken in setting to ensure that shaft alignment is perfect when gears are in mesh.

It is recommended that pump and gears be set up with

shafts in line and gears in mesh and then bolted to their foundations.

In some cases one or more heavy springs have been inserted to hold gears in mesh and to prevent undue stress being placed on driving gear. It is believed that this is a desirable feature and it is recommended for all cases.

f. The following sizes of gears are recommended:

Size of Pump.	Minimum	Diameter	of Gears.
	7″ face	9″ face	12″ face
500 gal.	24″	21″	18″
750 gal.	30″	24″	21″
1000 gal.	36″	30″	24″
1500 gal.		36″	30″

g. Friction gears to be protected by a strong sheet metal casing or cover securely fastened to the bed plate.

This to prevent grease and oil from getting into the grooves.

25. *Setting.*

a. Bed plate and supports for gearing to be of heavy construction, well bolted down, and capable of withstanding any strain that is liable to be put upon them. Pump must be securely fastened to firm foundation so as to be practically free from vibration. Good brick, concrete or masonry foundations are the best. Heavy I beams or wooden beams may be employed. No bolts to be used less than $\frac{3}{4}''$ in diameter.

26. *Clutch.*

a. Except where there is an independent wheel for pump alone, a reliable clutch should be provided so that main shafting beyond the pump can be thrown out of operation when pump is running. This to be located near pump or to be otherwise arranged so as to be readily accessible in case of fire.

27. *Priming Tank.*

a. If rotary pump takes water under lift, there must be a priming tank of at least the following capacity:

Size of Pump.	Size of Priming Tank.
500 gals.	200 gals.
750 gals.	300 gals.
1000 gals.	400 gals.
1500 gals.	500 gals.

b. This tank to be kept full of water at all times. To be connected with main casting over pump by at least a 2″ pipe, preferably of non-corrosive material. This pipe to contain a straightway brass check valve located close to pump and an approved indicator gate valve located so as to be readily accessible.

NOTE.—Priming tank should be located so that both tank and connections are as free from danger of damage by fire as is the pump, and preferably in the pump room.

28. *Location.*

a. Pump should be located in respect to its water supply, so that lift is not over 6 feet where possible. Where lift is over 15 feet or suction is over 250 feet in length a foot valve to be placed on end of suction pipe. Only such valves to be used as are approved by the Underwriters having jurisdiction.

b. Suction pipe to be provided with a strainer in all cases where there is liable to be foreign matter in the water. Strainer to be of brass or copper wire $\frac{1}{3}$ to $\frac{1}{2}$″ mesh, with an area at least five times that of the suction pipe.

c. Pump to be located where easy of access and as free as possible from danger by fire. The following locations are recomended in the order given:

1—Detached pump house well isolated from other buildings.

2—Pump room of ample size with standard fire cut-off from all adjoining buildings.

3—Inside main building enclosed in a room of fire resisting construction with passageway of similar construction to outside of building.

Where brick or terra cotta are not feasible expanded metal and cement is recommended as an inexpensive and desirable construction for such a room.

The method of locating rotary pumps in basements not cut off, but with pump arranged to start from outside of building, is not desirable, and if used great care must be taken that starting valve and priming valve and all other similar valves as well as wheels or other source of power be arranged to be operated from the same point.

Where there are several pumps in different buildings not all subject to one fire the requirement concerning cutting off of pump may be sometimes waived.

d. Pump room to be heated or pump and connections to be otherwise arranged so that there will be no danger of freezing in cold weather.

Where pump is not properly enclosed it may be sometimes satisfactory to tap a 1-inch steam pipe into suction pipe with a gate valve located close to suction pipe.

TESTS FOR ACCEPTANCE.

29. *Test for Smoothness of Action.*

Provide outlets for the water, start the pump, bringing up the pressure gradually to 100 pounds by controlling the speed where feasible or by aid of the starting valve where the speed is constant. The pump should run smoothly at its full rated speed, without considerable pounding or jar.

30. *Test with Maximum Working Pressure.*

With care in handling, shut off first one stream and adjust the safety valve so that it does not waste, letting the pressure increase; in this way shut off streams enough to cut the discharge down to about half the normal and see if the

pressure can be maintained at 150 pounds, or, under some conditions and with careful handling, at 175 or 200 pounds.

31. *Test for Maximum Delivery.*

Where speed can be increased, add additional streams and increase the speed until the pump is running at least 25 per cent. above the normal, and see how fast the pump can run, maintaining serviceable fire pressure, before objectionable pounding and vibration occur.

32. *Test of Capacity of Relief Valve.*

Adjust the relief valve so that it will open at 100 pounds; shut the main outlet valve and the hose gates, discharging all the water through the relief valve and the starting valve; then, with the pump at full speed, close the starting valve slowly. The relief valve should carry the total discharge of the pump at its full rated speed and not let the pressure rise above 125 pounds.

In general, where a pump is properly set up and handled it should be able to satisfactorily perform all of these tests.

APPENDIX.

NOTE.—Appendix to Rules of National Board of Fire Underwriters for Rotary Fire Pumps.

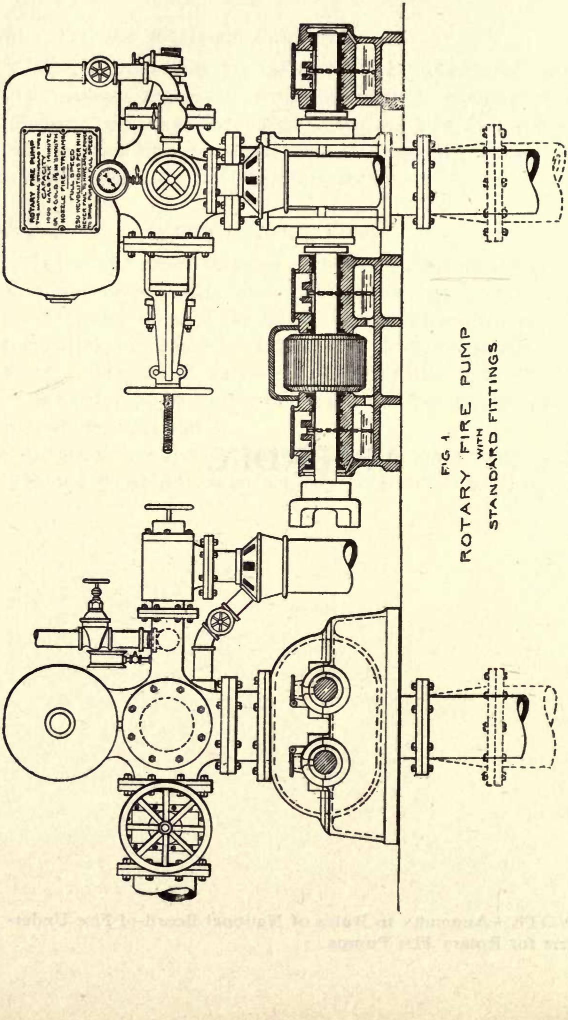


FIG 1
ROTARY FIRE PUMP
WITH
STANDARD FITTINGS

TYPE B.

Specifications for a Type of Rotary Pump Differing Radically From Present Types and Called Type B.

THESE SPECIFICATIONS ARE RECOMMENDED, BUT NOT REQUIRED.

The rotary pump which these specifications would require is merely a pump of the well-known "twin rotary" type, built in a very substantial manner and with certain improvements suggested by the experience of inspectors in the field.

The principal points of difference between a rotary pump so built and the ordinary commercial pump are:

1st. The water passages are made larger than in pumps hitherto built, so that there is less loss of pressure in getting water to and from the pump.

2nd. The pump is "rust-proofed" so that it may start instantly after disuse, by making its working cams and water casing of solid composition instead of cast iron.

3rd. The shafts are made heavier and the bearings more liberal, with special arrangements for keeping these bearings oiled and in readiness for instant use.

4th. The gears are made of forged steel, are supported on each side, are accurately cut, and run in a bath of oil.

5th. A special discharge casting and air chamber with certain fittings is furnished with each pump. These fittings include a pressure gage, a relief valve and cone, a priming pipe and valve, a starting valve, two to six hose valves and a capacity plate.

By reason of the larger passageways and pipes, heavier construction, better material used, superior design, and added attachments, a pump so built will cost more than the usual rotary pump, but the increased efficiency and reliability of the improved pump when suddenly called upon for fire service will, it is believed, fully warrant this extra cost.

Finally, it should be remembered that these specifications cover only the outlines of the design, and that all pumps built under them will not be of equal merit, for certain of the pump factories possess a broader experience and better shop facilities than others; and that the responsibility for first-class workmanship and strength of materials rests on the pump manufacturers and not on the insurance companies.

---

1. *Workmanship.*

a. The general character and accuracy of foundry and machine work must throughout equal the best practice of the times as illustrated in geared machinery of similar horse power and rotative speed.

This refers to strength of details, accuracy of foundry work, accuracy of fits, construction and alignment of shaft bearings, character of gear cutting, and does not apply particularly to exterior finish.

2. *Twin Rotary Pumps Only.*

a. Only twin rotary pumps having two shafts and positive displacement cams are acceptable.

3. *Sizes of Pumps.*

a. Only the four different sizes given in the following table will be recognized as approved rotary fire pumps.

STANDARD SIZES FOR ROTARY FIRE PUMPS.

Nominal Gals. Per Min.	Approximate Width of Buckets.	Distance Between Centers	Speed Rev. Per Min.	No. of $1\frac{1}{8}''$ Streams.	Approximate Horse-Power Required.
500	8″	7″–8″	275	2	60
750	9″ or 10″	8″–9″	275	3	90
1000	10″	9″–10″	250	4	120
1500	12″	10″–12″	250	6	180

The multiplicity of odd sizes of rotary pumps is confusing and undesirable, and in the past different makers have rated their pumps arbitrarily as to their capacity, giving to purchasers an incorrect idea as to their actual possibilities for fire service.

The above dimensions for buckets or cams and the distance between centers are, as stated, only approximate. The use, however, of short centers and wide cams is undesirable and should be avoided, as it unnecessarily lengthens the shafting and pump. On the other hand, the use of a narrow bucket—narrower than the usual centers—makes it difficult to provide ample suction and discharge openings in the pump casing.

The theoretical amount of power necessary to give a pressure of 100 pounds per square inch with a delivery of 100 gallons per minute is 5.34 H. P. This includes no allowance whatever for friction of water, for slip, and for friction in the pump itself and in the driving gear. Experience with the pumps now in use shows that those losses, as pumps are ordinarily found set up, about double the power necessary, so that 12 H. P. is usually required for each 100 gallons per minute delivered at 100 pounds pressure, and 30 H. P. is the usual allowance for each good 1⅛-inch stream.

It is desirable to keep the power required as small as possible, as there is often a limited power available where it is desired to place a rotary pump. It is hoped that with an improved pump and better method of driving, the total power required may be materially less than in the average pump found to-day.

b. The standard allowance for a good 1⅛ (smooth nozzle) fire stream is 250 gallons per minute.

A so-called ''ring nozzle'' discharges only three-fourths as much water as a smooth nozzle of the same bore, and is not recommended.

From fifteen to twenty automatic sprinklers may be reckoned as discharging about the same quantity as a 1⅛-inch hose stream under ordinary practical conditions as to pipes supplying sprinkler and hose systems respectively.

4. *Capacity.*

a. The displacement of the rotating cams in a rotary pump will not alone tell how many gallons per minute a pump can deliver, and it is not reasonable to estimate capacity on

the basis of the displacement of the cams per revolution multiplied by the number of revolutions per minute. A liberal allowance must be made for slip and for by-passing back into suction at the point where cams mesh together.

b. The capacity of a rotary pump depends as well upon the speed at which it can be run, and the speed depends largely upon the size and arrangement of its water passages and upon the manner in which its power-drive, gearing and shafting have been fitted up.

c. It is all right to run rotary fire pumps at the highest speed that is possible without causing violent vibration or hammering in the pipe system. Considerations of wear do not affect the brief periods of fire service or test.

d. Pumps must deliver when new 20% more water than called for by preceding table.

e. Pumps must be so built that they can be safely run at a speed 25% higher than that given in the table at 100 pounds water pressure.

Twenty per cent. margin is to allow for some wear and still have pumps which will deliver their full rated capacity. The requirement for ability to withstand 25 per cent. excess speed is comparable with the possibility ordinarily existing in steam pumps to run them above the rated speed. It is desirable that a rotary pump should have practically the same discharging capacity as a steam pump of equivalent rating.

5. *Capacity Plate.*

a. Every rotary fire pump must bear a conspicuous statement of its capacity securely attached to the inboard side of air chamber, thus:

....*

ROTARY FIRE PUMP.

NATIONAL STANDARD—TYPE B.

CAPACITY.

750 Gallons per Minute, or
3 Good $1\frac{1}{8}$-inch Smooth Nozzle
Fire Streams.

Full Speed.
275 Revolutions per Minute.
Never fail to have ample power to drive pump at full speed.

*Name of pump manufacturer to go here.

b. This plate must have an area of not less than one square foot and must be of an alloy at least $\frac{2}{3}$ aluminum, the remainder being zinc. The letters must be at least $\frac{1}{2}$ inch in height, plain and distinct, with their surface raised on a black background and buffed off to a dead smooth finish.

c. A smaller plate of composition must be attached to casing head, bearing the size of pump, shop number, and the name of shop in which the pump was built.

This plate may be cast on the bronze head where desired.

6. *Strength.*

a. Maker must warrant each pump built under these specifications to be at time of delivery in all its parts strong enough to safely withstand and be substantially tight under 240 pounds water pressure, and must agree to so test it before shipment from his works.

7. *Shop Inspection.*

A systematic shop inspection must be given to each pump, to insure complete workmanship and to prevent the use of defective parts, improper materials, or the careless leaving of foreign matter in any part of the pump.

THE PUMP.

8. *Style of Pump.*

a. The general arrangement of gears, shaft bearings, and pump casing required is shown in Figure 1. Pumps must have their two shafts geared together with one set of gears, each gear being supported by two bearings placed close up to the gears on either side. A third bearing supporting the tail end of each shaft must be provided at the other end of pump casing.

b. The span between this third bearing and the inboard bearing next to gear must be as short as possible, to avoid any deflection of the shaft.

c. The power-drive must in every case be connected to the gear end of the shaft.

d. These three bearings must form a part of a substantial bed plate, rigidly supporting the pump casing in perfect alignment with the bearings.

e. The pump casing must be surmounted by a special discharge casting with openings arranged as in Figure 1.

9. *Pump Casing.*

a. The pump casing and casing heads must be of solid bronze composition, made from new stock. The thickness of this shell and heads must not be less than in the following table:

Size of Pump.	500	750	1000	1500
Thickness of shell........	9/16″	⅝″	11/16″	¾″
Thickness of head.........	⅝″	⅝″	¾″	¾″

The shell and heads should be ribbed sufficiently to prevent any destruction of pump casing when working against the most severe conditions noted in Articles 29, 30, 31 and 32, pages 19 and 20, under Tests of Acceptance.

b. The bolting of the several parts of casing, heads and suction and discharge pieces must be such that the maximum stress at bottom of screw thread will not exceed 10,000 pounds per square inch (disregarding for the moment the initial stress due to setting up nuts) for a water pressure of 200 pounds per square inch figured out to the center line of the bolts.

No bolt or stud less than ⅝″ should be used to assemble parts of casing subject to the strain of water pressure. All such bolts or studs must be of Tobin bronze.

10. *Case.*

a. The rotating cams must be cast in one piece, of solid bronze composition. Their working surfaces must be accurately machined to fit the casing in which they revolve, and properly mesh into each other.

b. Each cam must be secured to its shaft by a standard-sized key running the entire width of cam.

The cams must be forced onto their respective shafts under heavy pressure, so that the subsequent keying will not throw them out of center.

c. The number of teeth or buckets in each cam should not exceed six or seven, nor is it desirable to use so few as to fail to secure smooth running.

A large number of buckets is likely to result in a weak form of tooth, or, if the tooth is made strong, the capacity of the pump is cut down. On the other hand, there is some evidence that too few buckets are likely to result in a pump which will not work without objectionable noise and vibration. It is important that there be no space in the buckets in which water may be trapped and squeezed, as this tends to make the pump pound.

While not desiring to restrict manufacturers, we advise not less than five and not more than seven buckets on each

cam, although strength of design and smoothness in running will be the main guiding features in determining final acceptance.

The use of packing strips to insure tightness of cam in casing is not desired. While in clear water such construction may be satisfactory, for the rough and only occasional use of the average fire pump the simpler form of construction is believed safer.

11. *Shafts.*

a. The shafts carrying the gears and cams must be of the best forged steel, and to be of a diameter at gear bearings not less than as given in the following table:

Size of Pump.	500	750	1000	1500
Distance between inner edges of the cam bearings.......	17″	18″	20″	22″
Diameter of shaft at bearing	$2\frac{3}{4}$	3	$3\frac{1}{2}$	4

These sizes are larger than necessary to simply resist torsional strain, as they must be sufficiently stiff to prevent much deflection for water pressures of 200 pounds which might occasionally be needed.

b. The shafts between the bearings and the cams must be protected from corrosion by a covering of bronze composition forced on into place.

c. The two shafts must extend beyond the bearings at the gear end a sufficient distance to permit keying on a driving coupling. One such coupling must be furnished with each pump.

12. *Stuffing Boxes.*

a. Stuffing boxes must be of a special and compact design, so as to prevent an excessive distance between main bearings.

To avoid the use of very large shafts, the distance between bearings must be kept as small as possible. The special type of stuffing box shown in Figure 2 suggests one method

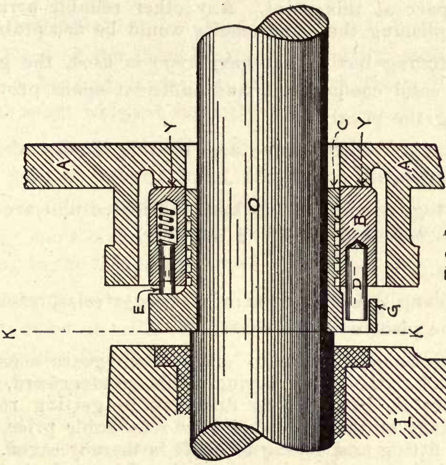
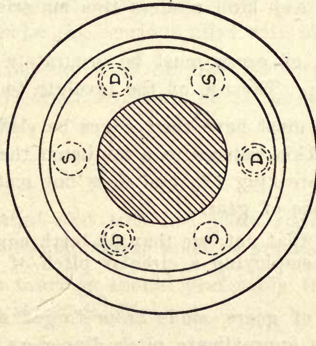


FIG. 2
WATER JOINT AS A
SUBSTITUTE FOR STUFFING
BOX ON ROTARY PUMP.



SECTION ON K – K

KEY—
A - CASING OF PUMP.
C - SLEEVE, FORCED TIGHT ON SHAFT.
B - SHELL IS A SLIDING FIT ON SLEEVE C., BUT TURNING WITH C
BY PINS D-D-D ENGAGING WITH COLLAR G.
G - COLLAR CAST WITH C.
I - BEARING FOR SHAFT.
O - SHAFT CARRYING CAM AND GEAR, SPRINGS S ACTING ON PINS E HOLD
THIS SHELL UP AGAINST Y MAKING A WATER TIGHT JOINT.

of saving space at this point. Any other reliable arrangement accomplishing the same results would be acceptable.

b. If a stuffing box of ordinary type is used, the gland must be of solid composition, and sufficient space provided for inserting the packing.

c. The shaft must not have any bearing at the stuffing box or casing head.

Such bearings are difficult to keep lubricated and are subject to rapid wear due to grit in the water.

13. *Gearing.*

a. Each pump gear must be of forged steel, preferably forged in one piece with the shaft.

Manufacturers preferring to make these gears separate from the shaft, fitting and keying them on afterward, may do so. There is, however, no difficulty in getting rough-turned forgings of this character at a reasonable price, and the work of fitting and keying to shaft is thereby saved. Steel castings have been proposed for this work, but the uncertainty of obtaining sound castings free from blow holes or porosity of any kind renders this material of doubtful reliability.

b. The teeth of gears must be accurately cut to insure smooth running. The use of the involute tooth is advised.

c. The gears must have their edges beveled off as shown in Figure 1. This reduces to a minimum the possibility of teeth corners breaking off, and does not materially reduce the working face of gear.

It is advised that not less than 20 teeth nor more than 30 teeth be used, employing a circular pitch of from 1¼-inch to 1½-inch.

d. The face of gears, made from forged steel, must not be less for the approximate pitch diameters given than as in table below, measuring on the pitch surface:

Size of Pump.	500	750	1000	1500
Approximate pitch diameter....	8″	9″	10″	12″
Face of gears................	4″	5″	6″	7″

14. *Bearings.*

a. Each of the three bearings supporting each shaft must have a bearing length at least three times the diameter of the shaft which it supports.

b. Each bearing must be lined throughout its entire length with the best babbitt metal, finished to at least ⅜-inch thick.

The babbitt after being cast into place must be thoroughly hammered and then all three boxes bored out at one setting in the boring machine.

c. The use of removable boxes is acceptable only when they are so fitted up with cylindrical machined fits as to be interchangeable, thereby maintaining perfect alignment of the shafts and pump casing.

d. Liberal-sized oil grooves must be provided, so as to insure lubrication over the entire bearing.

e. Each bearing must be provided with an endless chain oiler of durable construction, its lower part running in a chamber cast under the bearings filled with oil.

f. Each bearing cap must be provided with a hinged lid large enough to permit of inspection of the bearing and the application of oil.

15. *Bed Plate.*

a. A substantial cast iron bed plate rigidly supporting the bearings and pump casing must be provided.

b. The shaft bearings should preferably form a part of this casting, as shown in Figure 1.

c. There must be provided a chamber or basin cast in this bed plate directly under the gears and the several bearings, for the holding of a quantity of oil in which the gears and chain oilers will run. It will be desirable to connect all of these oil basins together, so as to equally distribute the oil to all basins as long as any remains in the bed plate.

d. A cast iron hood must be provided and fitted over the gears in such a manner as to entirely enclose them and also prevent the escape of oil from the gears during the operation of the pump.

This hood should be secured to the bed plate by several small bolts.

e. From four to six bolt holes, 1″ to $1\frac{1}{4}$″, varying with the size of the pump, must be provided in bed plate, so arranged as to properly secure it to foundation.

16. *Suction and Discharge Openings.*

a. The openings in pump casing for suction and discharge must not be less than as given below:

Size of Pump.	500	750	1000	1500
Suction inlet....................	6″	8″	8″	10″
Discharge outlet................	6″	8″	8″	10″

b. Where pump takes its water under a head, suction pipe may be of the same size, but with a suction lift of 10 feet or more and a length of pipe exceeding 20 feet, or with more than two elbows, suction pipe 2 inches larger must be used, and a special reducing casting must be provided to connect this pipe with the pump.

c. A special discharge casting must be furnished and bolted to the top of pump casing. This discharge piece and air chamber should preferably be cast in one piece.

Openings must be provided in this discharge casting of such sizes as are given in table below for the purposes specified.

Of the two openings on opposite sides, one must be provided with blank flange and the other left for attaching a hose connection piece. At right angles to these two openings there must be provided the main discharge outlet and the relief valve outlet, all shown in Figure 1.

Conveniently arranged openings must be provided for priming connection and for a starting or air valve pipe.

Size of Openings in Discharge Casting.

Size of Pump.	500	750	1000	1500
For main discharge	6″	8″	8″	10″
The two opposite sides for hose connection	5″	6″	7″	8″
For relief valve	3″	3½″	4″	5″
Priming connections	2″	2″	2″	2″
Air valve	2″	2½″	2½″	3″
Air chamber neck	5″	6″	6″	8″

17. *Standard Flanges.*

a. Standard flanges and bolt lay-outs, as adopted by the Master Steam Fitters July 18, 1894, must be used on all of the above pipe connections.

Do not drill bolt holes on center line, but symmetrically each side of it.

18. *Air Chamber.*

a. An air chamber in accordance with the sizes given in the following table must be provided with all pumps. If the air chamber is cast iron the pump manufacturers must warrant that it has been subject to a hydraulic test of 400 pounds per square inch before it is connected to pump.

It is to be thoroughly painted inside and outside to diminish its porosity.

Size of Air Chamber.

	Air Chamber is to contain
500-gallon pump	15 gallons
750-gallon pump	20 gallons
1000-gallon pump	25 gallons
1500-gallon pump	35 gallons

The exact shape of air chamber is not important. The design illustrated in Figure 1 saves height and makes the pump run more steadily by keeping the whole weight lower.

19. *Pressure Gage.*

a. A pressure gage of the Lane double-tube spring pattern with 5-inch case must be provided with the pump and connected near to inboard side of air chamber, as shown in Figure 1, by a ¼-inch cock with lever handle.

The dial of this gage should be scaled to indicate pressures up to 240 pounds, and marked "WATER."

This kind of gage is used on locomotives and is the best for withstanding the vibration which causes fire pump gages to be often unreliable. Moreover, this double spring form is safer against freezing.

20. *Hose Valves.*

a. Hose valves must be provided and included in price of pump as follows:

For 500-gallon pump, 2 hose valves.
For 750-gallon pump, 3 hose valves.
For 1000-gallon pump, 4 hose valves.
For 1500-gallon pump, 6 hose valves.

These are to be 2½-inch straightway brass valves, without cap, and of heavy pattern, good design and workmanship. The hose screw at end of these valves is to be fitted to a hose coupling furnished by the customer, or, where this cannot be procured, may be left with the thread uncut.

b. A hose connection casting must be provided and designed to bolt to the pump discharge casting or to a pipe flange where it is desired to locate the hose connections away from the pump. This casting must be fitted with such a number of 2½-inch pipe openings as the size of the pump demands. See Figure 1.

21. *Safety Valve.*

a. A safety or relief valve of approved make is to be regularly included in the price, and is to be attached to each pump preferably extending horizontally to one side of pump, as shown in Figure 1, so that its hand-wheel for regulating pressure is within easy reach. This hand-wheel

must be marked very conspicuously with word "OPEN" and arrow to show the direction.

b. This valve is to be set ordinarily at a working pressure of 100 pounds to the square inch, and is to be of such capacity that when set at 100 pounds it can pass all the water discharged by the pump at full speed at a pump pressure not exceeding 125 pounds per square inch.

For 500-gallon pump, a 3-inch valve.
For 750-gallon pump, a $3\frac{1}{2}$-inch valve.
For 1000-gallon pump, a 4-inch valve.
For 1500-gallon pump, a 5-inch valve.

c. The relief valve must discharge in a vertical downward direction into a cone or funnel secured to the outlet of the valve.

The valve must be so attached to the delivery casting and discharge cone by flange connections as to permit of its ready removal for repairs without disturbing the waste piping.

22. *Discharge Cone.*

a. This cone should be so constructed that the pump operator can easily see any water wasting through the relief valve, and its passages should be of such design and size as to avoid splashing water over into the pump room.

b. The cone must also have a tapped connection for the air-vent pipe, and the arrangement must be such that the pump operator can easily tell whether water is coming from the air pipe or is wasting through the relief valve.

c. The cone should be piped to some point where water can be wasted freely, the waste pipes being as below:

Size of Pump.	Diameter of Waste Pipe from Cone.
500-gallon	5 inches.
750-gallon,	6 inches.
1000-gallon,	7 inches.
1500-gallon,	8 inches.

The waste pipe can pass down to floor at side of pump, as in Figure 1. It should be piped in such a way that steam and gases from other drains or waste pipes will not work back through it and by being troublesome in the pump room suggest the covering of the cone in any way, as it is desirable that the pump operator should always be able to see instantly any waste from the relief valve or air vent.

This cast-iron cone, connected to the safety valve and air vent, is included in price of pump, but the waste pipe beyond it is not.

23. *Starting Valve.*

a. There must be a tapped pipe connection at some convenient point on discharge casting, of such size as given in table below, to which must be fitted a straightway valve of the outside screw and yoke pattern. This must be connected to the discharge cone in such a manner that the discharge of water at this point can be plainly seen by any one in attendance.

Size of Pump.	500	750	1000	1500
Size of starting valve..........	2″	2½″	2½″	3″

The object of this valve is two-fold: It first relieves the pump of any air discharged in starting up; and, second, it affords the attendant a means of gradually raising the pressure in the pipe system and avoiding any water hammer and the possible blowing out of a joint.

It is generally impractical to control the speed of a rotary pump, as it can be controlled in a steam pump. The rotary pump discharges its full quota of water as soon as it picks it up, and the starting valve herein specified will discharge most of it until the attendant closes it, thereby gradually bringing the pressure up to maximum in the pipes beyond it. The starting valve answers in a rotary pump the same purpose as the throttle valve in a steam pump—to control the water pressure.

CONNECTION TO POWER.

(The suggestions here made are preliminary, and it is expected that eventually more details as to size of gears,

shafts, frames, etc., will be given; the following is, however, sufficient to show the general character of the design desired.)

24. *Direct Connection.*

a. The best arrangement is a permanent and direct connection between the pump and the source of power. In a few cases this is possible, as where a special water-wheel with head sufficient to give proper pump speed is provided. Again, gas engines in the future may under some circumstances be used for this work and make direct connection possible.

b. Where the speed of the motive power is not right for the pump, but where there is a special wheel, electric motor, or other power for the pump, direct connection may still be provided through spur gears.

25. *Grooved Friction Gears.*

a. Grooved friction gears which give the speed increase generally necessary where driving from water powers, and at the same time furnish a friction coupling which can be thrown in without shutting down the wheel, are the most common arrangement at present. Such gears waste power, and, due to the heavy pressure with which they must be forced together, often cause heating of the bearings. Again, they not uncommonly get out of line, so that as found they are frequently not a satisfactory means of transmitting power.

b. The convenience and cheapness of such gears will probably always make them desirable to some extent. It is believed that where properly designed, set up and maintained, such gears will do good work and could satisfactorily be used where there is ample power or where other methods are not available.

26. *Spur Gears and Clutch.*

a. The speed change often needed may be secured by a pair of spur gears and the power thus transmitted with moderate loss. With this arrangement some form of clutch must be used to connect the driving gear to the source of power, except in cases where the wheel or other power is used exclusively for the pump. A simple, inexpensive, but reliable clutch of rugged construction is desirable for this work, and the clutch would have to be so designed that it would not become inoperative should it by neglect be allowed to rust.

b. Under some conditions a plain, square jawed clutch which requires the stopping of the power before it is thrown in can be used. Some provision is then desirable to prevent such a clutch being thrown in while running, in a way to do harm.

c. Spur gears, one of which slides, have been used in the past, but there is always the danger that in the excitement of a fire the gears will be thrown in while the power is running, thus stripping the teeth, so that this method, without some guard which would absolutely prevent this accident, is not generally desirable.

27. *Design and Strength of Construction.*

a. Whatever method of construction is adopted, it is essential that the design be simple, rugged and with a good margin of strength at all points.

b. Bearings for friction gears must be especially liberal, as the pressure required causes heating. Simple and positive means of lubrication should always exist.

c. Gears, clutches and all other parts should be designed in accordance with the best established practice and with large factors of safety, as in rotary pump driving there

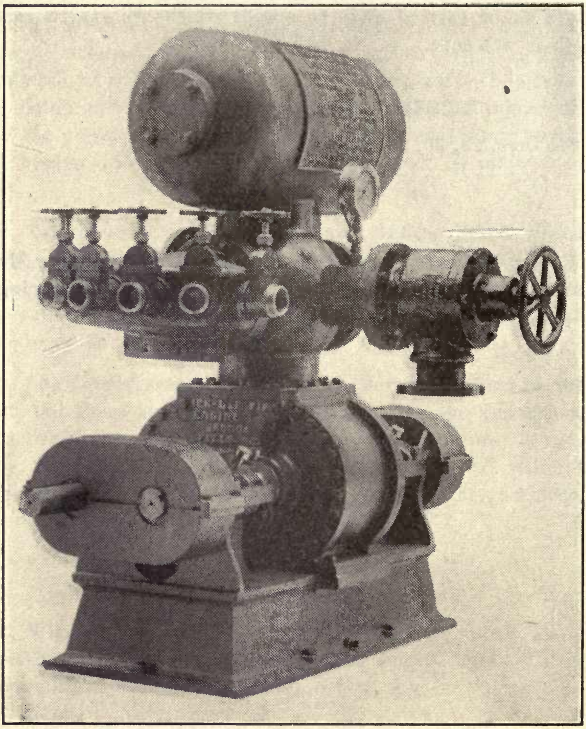
are likely to be severe shocks and the service is generally hard.

d. Any spur gears used should have cut teeth, as, for the power to be carried and the speeds which are run, a cast tooth is not safe.

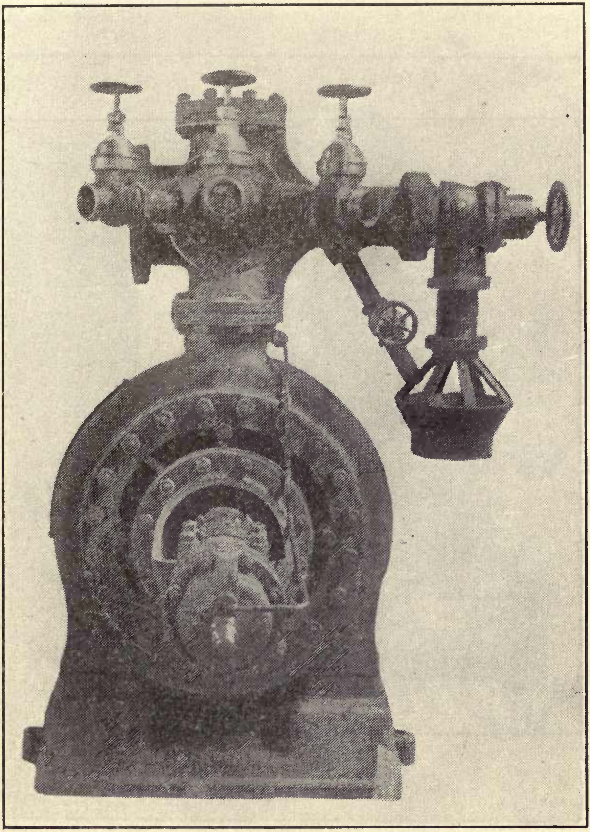
TESTS FOR ACCEPTANCE.

See Secs. 29, 30, 31, 32.

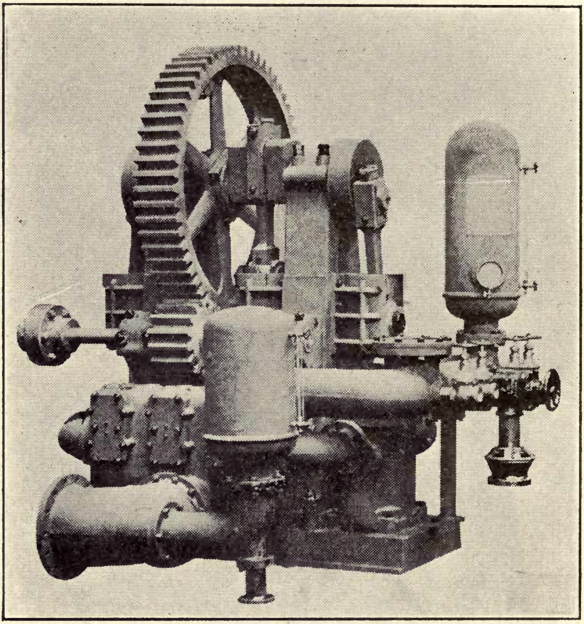
For amendments to National Board Rules adopted by the National Fire Protection Association since the foregoing rules were promulgated, see page 376.



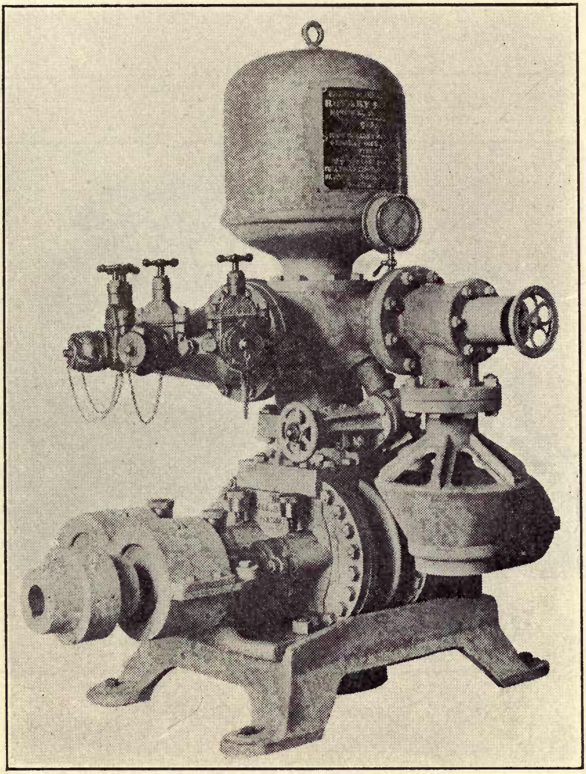
Type "A" National Standard Rotary Fire Pump.



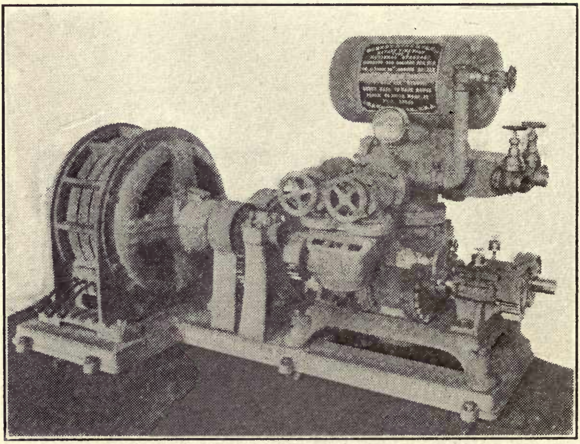
Centrifugal Fire Pump.



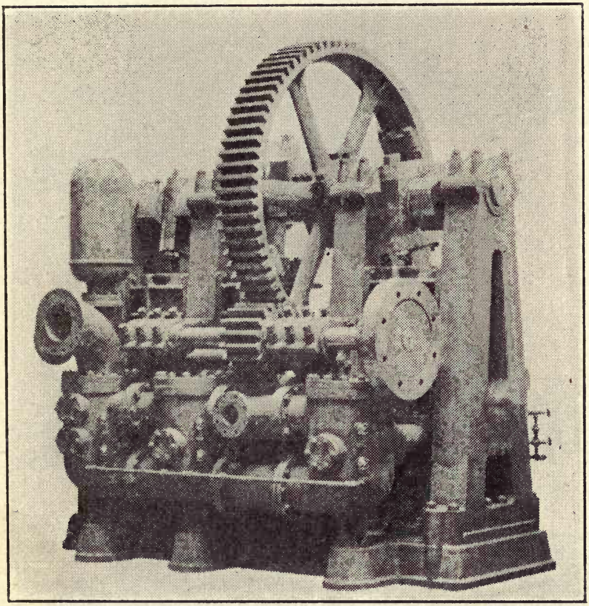
Single-Power Fire Pump.



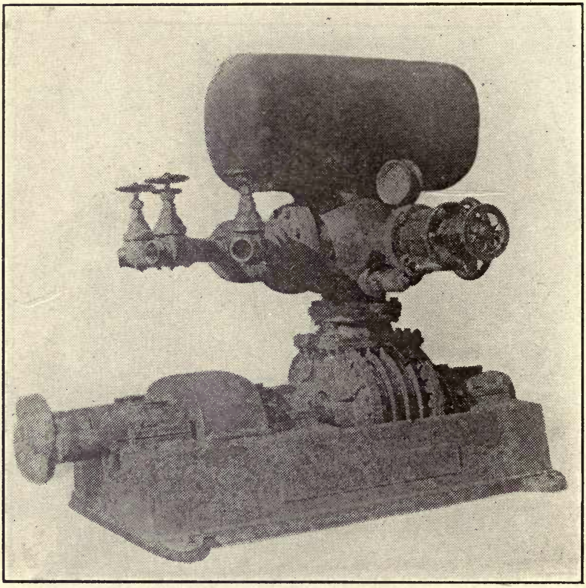
Type "A" National Standard Rotary Fire Pump.



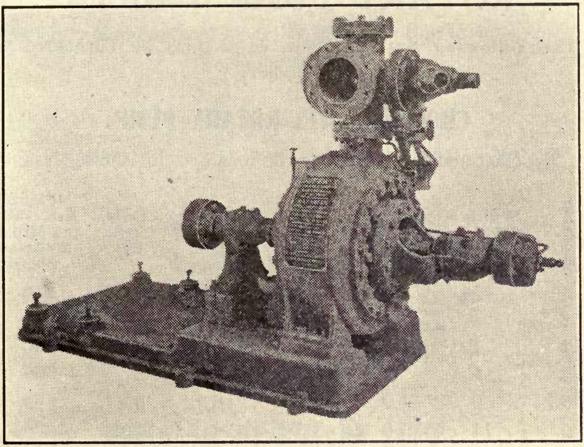
Type "A" National Standard Rotary Fire Pump.



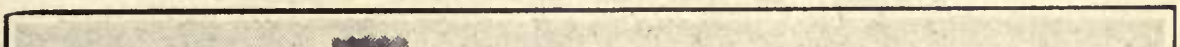
Triplex-Power Fire Pump.



Type "B" National Standard Rotary Fire Pump.



Centrifugal Fire Pump.



Underwriter Turbine Fire Pump-Direct Electric Drive.

ROTARY PUMP TABLES.

(The following data is from catalogues as furnished by the makers.)

CROCKER TWIN ROTARY PUMP.

Manufactured by E. D. Jones & Sons Co., Pittsfield, Mass.

Number	Width of Bucket Face in Inches	Distance Between Shaft Centers in Inches	Diam. of Suct.	Diam. of Disch.	Gals. per Rev.	Makers' Est. Gals. per Minute Moderate Speed
1	5½	5¼	3	2½	3/5	210
2	6	6	4	3	1	300
3	7	7	5	4	1½	400
4	8	8	5	5	2	500
5	9	9	6	6	3	800
6	11	9	7	6	4	1000
7	10	10	8	8	5	1250

FALES & JENKS ROTARY PUMP.

Manufactured by Fales & Jenks Machine Co., Pawtucket, R. I.

4	9	9	6	5	3⅞	1000
5	9	8	6	5	2⅞	750
6	8½	7	4	4	1⅔	500
7	8	6½	4	3	1⅓	400
7½	6½	5	3	3	⅔	200

GOULD ROTARY PUMP.

Manufactured by Gould Manufacturing Co., Seneca Falls, N. Y.

2	3⅛	4 5/16	2½	2	½	225
3	4¾	5¼	3	2½	1	400
4	4⅛	6 7/16	5	4	1⅔	500
5	6	7 11/16	6	5	2½	650
6	7½	9 1/5	8	6	4	1000

HOLLY ROTARY PUMP.

Formerly Manufactured by Holly Manufacturing Company, Lockport, N. Y.

Number	Width of Bucket Face in Inches	Distance Between Shaft Centers in Inches	Diam. of Suct.	Diam. of Disch.	Gals. per Rev.	Makers' Est. Gals. per Minute Moderate Speed
2	2	5	2	2	$\frac{1}{3}$	100
3	4	5	3	3	$\frac{2}{3}$	200
4	5	$7\frac{1}{4}$	4	4	$1\frac{1}{3}$	400
5	7	$10\frac{1}{2}$	5	5	$2\frac{1}{3}$	650
6	9	$10\frac{1}{2}$	6	6	$4\frac{1}{2}$	900
7	7	12	8 or 10	8 or 10	7	1400

HOLLY SILSBY ROTARY PUMP.

Manufactured by American Fire Engine Co., Seneca Falls, N. Y.

2	$2\frac{7}{8}$	3 13/16	$2\frac{1}{2}$	$2\frac{1}{2}$	1/5	110
$2\frac{1}{2}$	$3\frac{1}{2}$	5	$3\frac{1}{4}$	$3\frac{1}{4}$	$\frac{1}{2}$	250
3	$4\frac{3}{8}$	6	4	4	5/6	350
4	$6\frac{1}{4}$	6	$4\frac{1}{2}$	$4\frac{1}{2}$	$1\frac{1}{4}$	450
5	$6\frac{1}{8}$	$7\frac{1}{2}$	6	6	2	600
$5\frac{1}{2}$	$7\frac{3}{4}$	9	8	6	$3\frac{7}{8}$	1000
6	9	$9\frac{1}{2}$	8	8	$5\frac{1}{2}$	1200
7	9	$10\frac{1}{4}$	9	9	$7\frac{1}{3}$	1500

HOLYOKE ROTARY PUMP.

Manufactured by Holyoke Machine Company, Holyoke, Mass.

1	10	$8\frac{4}{5}$	8	8	4	1000
2	9	8	6	5	3	825
3	$8\frac{1}{2}$	7 1/5	5	4	2	600

HUMPHREY ROTARY PUMP.

Manufactured by Humphrey Machine Company, Keene, N. H

Number	Width of Bucket Face in Inches	Distance Between Shaft Centers in Inches	Diam. of Suct.	Diam. of Disch.	Gals. per Rev.	Makers' Est. Gals. per Minute Moderate Speed
1	6	6½	3 or 4	3	1	300
2	6	8½	5 or 6	4	1⅓	400
3	8	8½	6	4 or 6	1⅔	500
4	8	10½	6 or 8	6	2⅖	600
5	10	10½	8 or 10	6 or 8	3 1/5	800
6	12					1000
7	16					1200

HUNT ROTARY PUMP.

Manufactured by Rodney Hunt Machine Company, Orange, Mass.

4	9	9	6	5	3⅞	850
5	9	8	6	5	2⅞	700
6	8½	7 3/16	5	4	1⅔	500
7	8	6 13/32	4	3	1⅓	400

NONESUCH ROTARY PUMP.

Manufactured by Clark Machine Company, Turners Falls, Mass.

1	4	4	3	2½	⅓	133
2	6	5½	3½	3	¾	225
3	8	5½	4	3½	1	300
4	8	6½	5	4½	1½	412
5	10	6½	5½	5	2	550
6	12	8	6½	6	3	825
8	12	9	8	7	5	1250

RODNEY HUNT UNDERWRITER ROTARY FIRE PUMP.

Manufactured by Rodney Hunt Machine Company, Orange, Mass.

Number	Width of Bucket Face in Inches	Distance Between Shaft Centers in Inches	Diam. of Suct.	Diam. of Disch.	Gals. per Rev.	Gallons per Minute
2	18	8 13/16	10	10	6	1500
4	12⅜	8 13/16	10	8	4	1000
5	9⅜	8	8	8	3	750
6	6½	8	6	6	2	500
7	4	8	6	5	1½	300

RUMSEY ROTARY PUMP.

Manufactured by Rumsey & Company, Seneca Falls, N. Y.

Number	Width of Bucket Face in Inches	Distance Between Shaft Centers in Inches	Diam. of Suct.	Diam. of Disch.	Gals. per Rev.	Makers' Est. Gals. per Minute Moderate Speed
1	3⅛	4	2	2	⅓	100
2	3½	4¾	2½	2½	6/7	250
3	4¼	5¾	3	3	1¼	350
4	5	7⅜	4	4	1¾	450
5	7	8	5	5	2⅙	500

ROOTS ROTARY PUMP.

Manufactured by P. H. & F. M. Roots Co., Connersville, Ind.

1	5	5	5	4	⅞	140
2	6½	6½	6	5	2⅛	310
3	8½	8½	8	6	4¼	510
4	10	10	10	8	7	770
5	12	12	12	10	12	1200

TORRENT ROTARY PUMP.

Formerly Manufactured by H. M. Wiswell.

1	10	5½	3	3	1	300
4	11	6½	4	4	1½	450
5	14	8½	5	5	3	900

RULES AND REQUIREMENTS

For the Construction and Installation of

ELECTRIC FIRE PUMPS.

NOTE—The following is a reprint of the Rules and Requirements of the National Board of Fire Underwriters. (1904.)

1. *Current Supply.*

Whether any particular current supply will be satisfactory must be left more or less to the discretion of the Underwriters having jurisdiction, but any source should within reasonable limits meet the following requirements:

a. The Current should be furnished from a fireproof or semi-fireproof constructed station.

NOTE.—A station having brick walls, concrete floors, plank roof, and containing modern apparatus and equipment, will be considered as a "semi-fireproof" station. It is desirable to have the mains and feeders supplied by two or more stations, any one of which is capable of furnishing the necessary current. When two stations are available, good, non-fireproof stations may be accepted in place of fireproof, but fireproof stations should be chosen wherever possible.

b. The supply of current must be from mains and feeders which can furnish the necessary current at all times, day or night, every day in the year, and which can show a service record of no interruption in any one year, exceeding one-half hour, and not over four interruptions exceeding five minutes each.

c. The supply must have a reserve capacity such as to be in no way discommoded provided the maximum quantity needed, by a reasonable number of motors supplied, was suddenly called for in addition to the normal load of the circuit.

2. *Transmission of Current.*

a. Two circuits should be provided, either from the same or separate stations, entirely independent from the source of supply to the pump room, so arranged as to afford the least liability of interruption.

NOTE.—Two connections from different sections of an

Edison network, separated by one or more junction boxes, will be considered as complying with this requirement. In case of isolated plants, with complete conduits from dynamo room to pump room, one connection only would be required.

b. When the potential of the transmission circuit is over the maximum allowed for low potential systems as specified by the "National Electrical Code," so that transformers at the plant are necessary, those which furnish current for the motor shall be used for this purpose only, and must be connected without fuses in their primaries or secondaries.

c. The mains and feeders of these circuits must be of ample size that the maximum current necessary to supply the motor can be furnished without excessive drop.

NOTE.—A drop in excess of 10 per cent. will ordinarily be considered excessive.

d. The protective devices on the circuits at the source of power must be of such capacity that they will not open except from short circuit on the mains and feeders.

e. The wires leading from the source of supply to the motor must be installed in accordance with the requirements of the "National Electrical Code," with the exceptions noted under 2*b* and 2*d*, and in addition must be so arranged that liability to injury or accident will be reduced to a minimum.

NOTE.—A complete underground circuit from generating station to pump is strongly recommended and should be obtained when practicable. When such construction is not available, an overhead circuit may be allowed, but that part of the circuit adjacent to the plant or exposing plants, must be run with special reference to damage in case of fire. Where the pump room is a part of, or in close proximity to, the plant which the pump is designed to protect, the wires for some distance from the pump room must be underground.

f. Wires in pump room must have an insulation as called for in "National Electrical Code"—Rule 40—and Sections *a* to *d*, inclusive, and Section *h* of Rule 41. No wires carrying a potential over the maximum allowed for low potential systems as specified by the "National Electrical Code," shall be allowed in pump room.

3. *Pump Room and Transformer Vault.*

a. Pump Room must be of fireproof construction, thoroughly cut off from balance of plant, and so arranged that access can be had to it from the outside. The room should be used for no other purpose, must be arranged to allow for ample drainage, and must be thoroughly ventilated to the outer air.

b. When it is necessary to provide for transformers for pump motor at plant, they must be located in a fireproof vault, cut off from pump room and thoroughly ventilated to the outer air through a flue or chimney.

4. *Foundation.*

The foundations on which the motor and pump rest must be of substantial fireproof construction, as of brick, stone or concrete, the motor and pump being in alignment and securely fastened to their foundations.

5. *Transmission of Power.*

Motor must be connected to pump directly or by gearing having single reduction. Bearings must be self-lubricating and where gearing is used, must have bronze or other approved metal pinions.

6. *Motor.*

a. May be of either the continuous or alternating current type, and must be designed for voltages within the limits for low potential systems as specified by the "National Electrical Code."

b. Must be so protected that it will not be injured by water escaping from pump or connections.

NOTE.—It is desirable, and is strongly recommended, that the motor be made waterproof. In any event, it should be so protected that escaping water, as from a leaky stuffing box, the blowing out of packing, bursting of hose, etc., will not injure the motor or interfere with its operation.

c. Must have all revolving parts mechanically and electrically balanced.

d. Must have self-lubricating bearings.

e. Must be of such capacity that it can run the pump for ten (10) consecutive hours at its normal speed, when pump is delivering its full capacity at a pressure of 100 lbs. per square inch, without a rise of temperature in any part of more than 40° C. above the surrounding atmosphere.

f. At the end of test prescribed in Section *e* those parts of the motor designed to be insulated from each other must withstand the continued application for one minute of an alternating E. M. F. of 2,000 volts.

g. Other things being equal, preference will be given to the motor showing the highest efficiency.

h. Must be provided with a name plate stating the name of the manufacturer, the capacity in volts and amperes, and the normal speed in revolutions per minute.

7. *Means of Control.*

It is recommended that the motor be arranged to start automatically upon reduction of the pump discharge pressure, and to stop automatically when the pressure has reached the maximum desired. Manual control may, however, be permitted at the discretion of the Underwriters having jurisdiction, and both systems will be required if deemed advisable.

Automatic Controller.

a. Must substantially be waterproof.

b. Must be capable of starting the pump against a pressure not more than 10 pounds below that at which the relief valve operates, limiting the starting current to 125 per cent. of that required by the motor running at full speed, delivering water through the relief valves with all other pump (or discharge) outlets closed.

c. Must return to the starting position immediatly upon cutting out the motor, and must be so arranged that the motor cannot start until the controller has reached such position.

d. Must be constructed in a substantial and durable manner throughout, with special attention to permanency and reliability of contacts.

e. Must be provided with a name plate stating the name of the manufacturer, the voltage and maximum current for which the controller is designed, and the minimum permissible period at which it may operate repeatedly without damage from overheating.

Manual Controller.

f. Must substantially be waterproof.

g. Must be so proportioned that the motor can be started, under the most severe conditions that are liable to be met with in practice, limiting the starting current to 125 per cent. of that required by the motor running at full speed delivering water through relief valves with all other pump (or discharge) outlets closed.

NOTE.—Manually operated, variable-speed controllers of practicable size cannot meet the widely varying conditions of pump output which must be provided for in an equipment for fire service. It is therefore required that where the equipment is not automatic the motor shall be brought to speed by means of a starting box only, and shall continue running at full speed, discharging the surplus water, if any, through the relief valves.

h. The starting operation must be accomplished by the use of one handle or lever arm.

i. Must be constructed in a substantial and durable manner throughout with special attention as to permanency and reliability of contacts.

j. Must be so designed that if current is interrupted, the

lever or contact arm must be brought back to its off or starting position before current can be again applied. No overload release device will be allowed.

k. Must be provided with a name plate stating the name of the manufacturer, the voltage and the maximum current for which the starting box is designed.

8. *Switch-Circuit Breaker.*

a. A double throw switch must be provided at entrance of wires into pump room which can disconnect the motor from all sources of supply. The circuits called for in Section *a* under "Transmission of Current," to be connected at either end of switch, the leads to motor being connected at the center.

b. A circuit breaker in motor leads must also be provided, which shall be so designed as to be capable of interrupting the circuit without injury to itself.

NOTE.—The circuit breaker should be set to open at about 100 per cent. above maximum current, which the motor requires when running at normal speed, with pump discharging full capacity against 100 pounds pressure. Its function is solely to cut out the motor in case of a short circuit or accident. No metallic fuses to be allowed in the circuit.

9. *Pump.*

a. Pumps of the piston or plunger type, as regards construction, must comply with those requirements pertaining to the water end of "The National Standard" Steam Fire Pumps.

b. Pumps of the rotary type, as regards construction, must comply with requirements pertaining to Rotary Fire Pumps.

c. Pumps of the screw type must comply as far as material which enters into their construction, with rules governing Rotary Fire Pumps.

d. Name plate, suction and water supply, lift, priming

tank and connections, hose conections, gages, valves, air chamber, etc., must be as called for on Steam or Rotary Pump Specifications as the case may be.

e. Must be provided with two relief valves of the spring "Pop Release" type, attached direct to discharge casting, and to have hand-wheel for pressure regulation. Each valve must have same capacity as required in Steam or Rotary Pump Specifications for pumps of same size. Relief valves to discharge into a waste pipe having cone top with slide so that discharge can be made visible, and when the supply of water is limited, as from a special suction reservoir or cistern, the waste pipe must drain into such reservoir or cistern.

10. *Compression Tank for Automatic Pumps.*

a. Where automatic control is installed, the pump discharge must have direct connection with an air tank of sufficient size to prevent too frequent operation of the automatic starter, and too wide variation of pressure at any discharge which the pump is capable of supplying, and the requisite amount of air in the tank must be maintained by means of an air compressor.

NOTE.—This tank must be much larger than the air cushion ordinarily used to steady the discharge of reciprocating pumps, its function being to take a portion of the discharge while the pump is running at full speed and then supply the system after the pump has stopped and while the controller is recovering and again bringing the pump to speed.

b. The inlet to the tank must be of the same size as the discharge pipe from the pump, and contain a straightway gate valve of approved outside screw and yoke or other approved indicator pattern. This valve must be kept secured open with a padlock or riveted leather strap, exception being made only where a reliable system is maintained for permanently sealing all valves and for immediate notification of broken seals.

c. The tank must be provided with a suitable water gage, the two gage valves being ordinarily kept closed, and opened only to ascertain the water level in the tank.

11. *Approval.*

Each type of pump, together with motor and all controlling devices, to be submitted to Underwriters' Laboratories for test.

For amendments to National Board Rules adopted by the National Fire Protection Association since the foregoing rules were promulgated, see page 380.

U. S. GALLONS DISCHARGED BY ONE PISTON OR PLUNGER.

Estimated on piston speed of 100 feet per minute, of a double acting piston, no allowance being made for slip.

Diameter of Piston	Gallons per Minute	Gallons per Hour	Gals. per 24 Hours
1	4.07	244.7	5,875
1¼	6.37	382.5	9,180
1½	9.18	550.8	13,219
1¾	12.49	749	17,992
2	16.31	979	23,500
2¼	20.6	1,239	28,180
2½	25.5	1,530	36,720
2¾	30.8	1,851	44,424
3	36.7	2,203	52,878
3¼	43.1	2,586	62,064
3½	49.9	2,998	71,971
3¾	57.3	3,442	82,619
4	65.2	3,916	94,002
4¼	73.7	4,422	106,128
4½	82.6	4,957	118,971
4¾	92	5,523	132,552
5	102	6,120	146,880
5¼	112	6,745	161,934
5½	123	7,404	177,696
5¾	134	8,093	194,248
6	146	8,812	211,511
6¼	159	9,562	229,500
6½	172	10,344	248,256
6¾	185	11,152	267,600

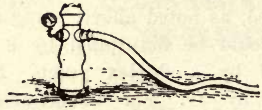
U. S. GALLONS DISCHARGED BY ONE PISTON OR PLUNGER—(Cont.)

Diameter of Piston	Gallons per Minute	Gallons per Hour	Gals. per 24 Hours
7	200	11,995	287,886
7¼	214	12,867	308,808
7½	229	13,769	330,478
7¾	245	14,700	352,300
8	261	15,667	376,011
8¼	277	16,660	399,852
8½	294	17,688	424,512
8¾	312	18,741	449,978
9	330	19,828	475,887
9¼	349	20,944	502,668
9½	368	22,092	530,208
9¾	388	23,280	558,720
10	408	24,480	587,518
10¼	428	25,716	617,184
10½	449	26,989	647,789
11	493	29,616	710,784
11½	529	32,374	776,993
12	587	35,251	846,046
12½	637	38,250	918,000
13	689	41,370	992,880
13½	743	44,610	1,070,640
14	799	47,980	1,151,536
14½	858	51,468	1,235,232
15	918	55,070	1,321,915
15½	980	58,800	1,411,200
16	1,044	62,668	1,504,046

U. S. GALLONS DISCHARGED BY ONE PISTON OR PLUNGER—(Cont.)

Diameter of Piston	Gallons per Minute	Gallons per Hour	Gals. per 24 Hours
16½	1,110	66,642	1,599,408
17	1,179	70,752	1,698,048
17½	1,249	74,964	1,799,136
18	1,322	79,314	1,903,550
18½	1,396	83,778	2,010,672
19	1,473	88,368	2,120,832
19½	1,552	93,120	2,234,880
20	1,632	97,920	2,350,080
20½	1,714	102,840	2,468,160
21	1,799	107,952	2,590,848
21½	1,886	113,154	2,715,696
22	1,974	118,482	2,843,568
22½	2,065	123,924	2,974,175
23	2,158	129,492	3,107,808
23½	2,253	135,186	3,244,464
24	2,349	140,958	3,382,992
24½	2,449	146,958	3,526,992
25	2,550	152,994	3,671,856
25½	2,653	159,179	3,820,300
26	2,758	165,484	3,971,630
26½	2,865	171,908	4,125,800
27	2,974	178,457	4,282,967
27½	3,085	185,130	4,443,125
28	3,199	191,922	4,606,125
28½	3,314	198,838	4,772,118
29	3,431	205,876	4,941,028
30	3,672	220,320	5,287,675

To compute the equivalent in Imperial gallons, multiply by .833. The gallons discharged, as noted above, being for one double acting plunger, should be multiplied by 2 to determine quantity discharged by a duplex pump. For single-acting triplex multiply by 1½. For double-acting triplex pump multiply by 3. For a greater or less piston speed than 100 feet per minute, calculations can be readily made.



PUMP INSPECTION

Discharge of Nozzles attached

HYDRANT PRESSURE indicated while Stream is flowing by Gauge attached to Hydrant, as shown.	1⅜-Inch Smooth Nozzle. Gals. per Min.			1¼-Inch Smooth Nozzle. Gals. per Min.			1⅛-Inch Smooth Nozzle. Gals. per Min.			1-Inch Smooth Nozzle. Gals. per Min.			⅞-Inch Smooth Nozzle, or 1-Inch Ring Nozzle. Gals. per Min.		
Lbs. per sq. in.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
5	90	92	103	80	82	90	70	71	75	59	59	62	47	47	48
10	127	131	146	114	116	127	99	101	107	83	84	87	66	67	68
15	155	160	179	140	143	154	121	123	131	101	102	106	81	81	84
20	180	185	206	161	164	179	140	142	151	117	118	123	93	94	96
25	201	207	230	180	184	200	156	158	169	131	132	137	104	105	107
30	220	226	251	197	202	219	171	173	184	143	144	150	114	115	118
35	238	245	272	213	218	236	184	188	199	154	156	162	123	124	127
40	255	262	291	227	233	253	197	201	213	165	167	173	132	133	136
45	270	278	309	241	247	269	209	213	226	175	177	184	140	141	144
50	284	293	325	255	260	283	221	224	238	184	186	194	147	148	152
55	298	307	341	267	273	296	232	235	250	193	195	204	154	155	159
60	311	320	357	279	285	309	242	245	261	202	204	213	161	162	167
65	324	333	371	290	296	322	252	255	272	210	213	221	168	169	173
70	336	346	385	301	307	334	261	265	281	218	221	230	174	176	180
75	348	358	399	311	318	344	270	275	291	226	228	238	181	182	186
80	359	370	412	322	329	357	279	284	301	233	236	246	186	188	192
85	371	382	425	332	339	369	288	293	310	240	243	253	192	193	198
90	381	393	437	341	349	379	296	301	319	247	250	261	197	199	204
95	392	403	449	350	358	390	304	309	328	253	257	268	203	204	209
100	402	414	461	359	368	400	312	317	337	260	264	275	208	210	215

Quantities are stated in United States gallons of 231 cubic inches.

TABLES.

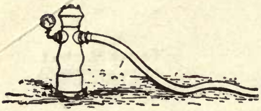
TABLE B.—No. 1 (From experiments of J. R. FREEMAN, 1888.)

to 50 Feet of 2½-inch Hose.

¾-Inch Smooth Nozzle, or ⅞-inch Ring Nozzle. Gals per Min.			1⅜-Inch Ring Nozzle. Gals. per Min.			1¼-Inch Ring Nozzle. Gals. per Min.			1⅛-Inch Ring Nozzle. Gals. per Min.			HYDRANT PRESSURE.
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Lbs. per sq. in.
36	36	37	75	76	84	66	67	70	56	56	59	5
50	50	51	108	110	118	94	96	101	80	81	84	10
61	61	62	132	135	144	115	117	124	98	99	103	15
71	71	72	152	155	167	133	135	143	113	114	119	20
79	80	81	170	174	187	149	151	159	126	128	133	25
86	87	88	187	191	205	163	165	175	138	140	145	30
93	93	95	201	206	221	176	179	189	149	151	157	35
100	100	101	215	219	237	188	191	202	159	162	168	40
106	106	108	229	233	251	200	203	214	169	172	178	45
112	112	113	241	245	264	211	214	226	179	181	188	50
117	117	119	253	257	277	221	224	237	187	189	197	55
122	122	124	264	269	289	231	234	247	196	198	205	60
127	127	129	275	280	301	240	244	257	205	206	214	65
132	132	134	285	291	313	249	253	267	212	213	222	70
137	137	139	295	301	324	258	262	276	219	221	230	75
141	142	144	305	311	334	266	270	285	226	228	237	80
145	146	148	314	320	345	274	279	294	233	235	244	85
149	150	152	323	329	355	282	287	303	239	242	252	90
153	154	156	332	338	364	290	295	311	246	249	259	95
158	159	161	340	347	374	298	303	319	253	255	266	100

NOTE.—The above figures for Ring Nozzle Discharges will apply to any ordinary form of Ring accurately enough for practical purposes, but apply especially to ordinary form of Ring Nozzle with square shoulder $\frac{1}{16}$ or $\frac{1}{8}$ inch deep.

Ring Nozzles with "under-cut" or "knife-edge" shoulder, discharge, as ordinarily constructed, about 3 per cent. less than quantity given above.



PUMP INSPECTION

Discharge of Nozzles attached

HYDRANT PRESSURE indicated while Stream is flowing by Gauge attached to Hydrant, as shown.	1⅜-Inch Smooth Nozzle. Gals. per Min.			1¼-Inch Smooth Nozzle. Gals. per Min.			1⅛-Inch Smooth Nozzle. Gals. per Min.			1-Inch Smooth Nozzle. Gals. per Min.			⅞-Inch Smooth Nozzle, or 1-inch Ring Nozzle. Gals. per Min.		
Lbs. per sq. in.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
5	75	79	93	70	72	82	62	64	71	54	55	59	44	45	47
10	107	111	131	98	102	116	88	91	100	76	78	83	63	63	66
15	131	136	160	121	125	143	108	111	123	93	95	102	76	77	81
20	151	157	185	139	144	164	125	128	142	107	110	118	88	89	94
25	169	176	207	155	161	184	139	143	158	120	122	132	99	100	105
30	185	192	226	170	176	202	152	156	173	132	134	144	108	110	115
35	200	208	245	184	190	218	165	169	188	142	145	156	117	119	124
40	214	222	262	197	204	233	176	181	201	152	155	167	125	127	133
45	226	236	278	209	216	247	187	192	213	161	165	177	132	134	141
50	239	249	293	220	228	260	197	202	224	170	174	186	139	142	148
55	251	261	307	231	239	273	207	212	235	178	182	195	146	148	155
60	261	273	320	241	250	285	216	222	245	186	190	204	153	155	162
65	272	284	333	251	260	296	225	231	255	194	198	213	159	161	169
70	282	294	346	261	270	307	233	240	265	201	205	221	165	167	176
75	292	304	358	270	279	319	241	248	275	208	212	228	171	173	182
80	301	314	370	278	288	329	249	256	284	215	219	236	177	179	188
85	311	324	382	287	297	339	257	264	293	222	226	243	182	185	193
90	320	333	393	295	306	349	264	272	301	228	233	250	188	190	199
95	329	342	403	303	314	358	272	279	309	234	239	257	192	195	204
100	337	351	414	311	322	368	279	287	317	240	245	264	197	200	210

Quantities are stated in United States gallons of 231 cubic inches.

TABLES.

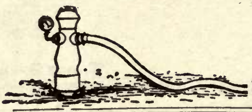
TABLE B.—No. 2. (From experiments of J. R. FREEMAN, 1888.)

to 100 Feet of 2½-inch Hose.

¾-Inch Smooth Nozzle, or ⅞-inch Ring Nozzle. Gals. per Min.			1⅜-Inch Ring Nozzle. Gals. per Min.			1¼-Inch Ring Nozzle. Gals. per Min.			1⅛-Inch Ring Nozzle. Gals. per Min.			HYDRANT PRESSURE.
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Lbs. per sq. in.
34	34	35	67	69	78	60	62	68	52	53	57	5
48	49	50	94	97	110	85	87	96	74	75	81	10
59	60	61	115	120	135	104	107	117	90	92	99	15
68	69	71	133	138	155	120	123	135	105	107	114	20
76	77	79	149	154	174	134	138	151	117	119	128	25
84	84	87	163	169	191	147	151	165	128	130	140	30
90	91	93	176	182	206	159	163	179	139	141	151	35
97	97	100	188	195	219	169	174	191	148	151	162	40
103	103	106	200	207	233	180	185	203	157	160	172	45
108	109	112	211	218	245	190	195	214	165	169	181	50
113	114	117	221	229	257	199	204	224	173	177	189	55
118	119	122	231	239	269	208	213	234	181	185	198	60
123	124	127	241	248	280	217	222	244	189	192	206	65
128	129	132	250	258	291	225	230	253	195	199	213	70
132	133	137	259	267	301	233	239	262	203	206	221	75
137	138	142	267	275	311	240	246	270	209	213	228	80
141	142	146	275	284	320	247	254	279	215	219	235	85
145	146	150	283	292	329	255	261	287	222	226	242	90
149	150	154	291	300	338	262	269	295	228	232	249	95
153	154	158	299	308	347	269	275	302	234	238	255	100

NOTE.—The above figures for Ring Nozzle Discharges will apply to any ordinary form of Ring accurately enough for practical purposes, but apply especially to ordinary form of Ring Nozzle with square shoulder $\frac{1}{16}$ or $\frac{1}{8}$ inch deep.

Ring Nozzles with "under-cut" or "knife-edge" shoulder, discharge, as ordinarily constructed, about 3 per cent. less than quantity given above.



PUMP INSPECTION

Discharge of Nozzles attached to

HYDRANT PRESSURE. indicated while Stream is flowing by Gauge attached to Hydrant as shown.	50 Feet 2½-Inch Hose.						100 Feet 2½-Inch Hose.					
	1¾-Inch Smooth Nozzle. Gals. per Min.			1½-Inch Smooth Nozzle. Gals. per Min.			1¾-Inch Smooth Nozzle. Gals. per Min.			1½-Inch Smooth Nozzle. Gals. per Min.		
Lbs. per sq. in.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.
5	110	114	136	97	101	115	86	90	114	80	83	101
10	154	162	193	138	143	163	122	128	162	113	118	143
15	190	198	237	169	176	200	150	157	198	138	145	176
20	219	229	274	196	203	232	173	182	229	160	167	203
25	245	256	306	219	227	259	193	203	256	179	187	227
30	268	281	335	239	248	283	211	222	281	196	205	248
35	290	303	362	259	268	306	228	240	303	212	222	268
40	310	324	387	277	286	327	244	256	324	226	237	286
45	328	344	410	294	304	347	258	272	344	240	251	304
50	346	363	432	310	321	366	272	287	363	253	265	321
55	364	380	453	325	336	383	285	301	380	265	278	336
60	380	397	473	339	350	400	298	314	397	277	290	350
65	395	414	492	353	364	417	310	327	414	288	302	364
70	410	429	510	366	378	432	321	339	429	299	313	378
75	425	444	528	379	392	447	331	351	444	309	324	392
80	439	458	546	391	405	461	344	363	458	319	335	405
85	452	472	563	403	417	476	354	374	472	329	346	417
90	465	487	579	415	429	490	364	385	487	339	356	429
95	477	500	595	427	441	503	374	396	500	348	366	441
100	489	512	610	438	453	515	383	406	512	357	375	453

NOTE.—This table was computed from formulas (2) and (7) of Appendix, "Freeman on Hydraulics of Fire Streams," in Trans. Am. Soc. C. E., Nov. 1889. Coefficient of discharge used = .974.

For **Underwriter Playpipe with Tip removed** (this outlet should be 1⅜ inches) use columns for 1¾-inch Smooth Nozzle.

TABLES.

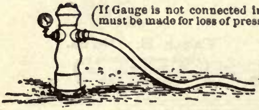
TABLE B.—No. 2A.
(From experiments of J. R. FREEMAN, 1888. Computed, 1900.)

various lengths of 2½-inch hose.

150 Feet 2½-Inch Hose.

1⅜-Inch Smooth Nozzle. Gals. per Min.			1¼-Inch Smooth Nozzle. Gals. per Min.			1⅛-Inch Smooth Nozzle Gals. per Min.			1-Inch Smooth Nozzle. Gals. per Min.			HYDRANT PRESSURE indicated while Stream is flowing by Gauge attached to Hydrant, as shown.
Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill-Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose."—Inside Rough.	Ordinary best quality Rubber-lined Hose.—Inside Smooth.	Lbs. per sq. in.
					80	56	60	67	45	50	56	5
81	91	118	88	91	110	81	84	94	69	73	79	10
107	117	146	108	112	134	97	101	119	86	90	99	15
130	138	168	123	128	155	113	118	136	100	103	114	20
147	154	189	139	145	171	127	131	152	112	116	127	25
163	170	207	153	159	187	140	144	165	122	126	139	30
179	184	225	163	171	203	150	155	178	132	136	151	35
190	196	239	174	183	216	160	166	190	141	145	161	40
200	208	254	185	194	229	170	176	201	150	154	171	45
210	220	267	195	205	241	179	186	212	158	163	180	50
220	230	279	205	215	253	188	195	223	166	172	189	55
229	241	292	215	225	265	197	204	233	174	179	198	60
238	251	305	224	234	277	205	212	243	181	186	206	65
248	260	317	232	243	287	213	220	252	187	192	213	70
257	269	328	240	251	297	220	228	261	194	199	221	75
265	277	338	248	259	306	228	236	269	200	205	228	80
273	285	348	256	267	316	235	243	277	207	212	234	85
281	294	358	264	275	325	242	250	285	212	218	241	90
288	302	368	271	283	334	248	257	293	218	224	247	95
295	310	378	278	290	342	255	263	300	223	230	253	100

Quantities are stated in United States gallons of 231 cubic inches.



(If Gauge is not connected in this manner, proper allowance must be made for loss of pressure between Gauge and Hydrant.)

PUMP INSPECTION

The degree of accuracy attained in estimating of the two preceding tables — B, No. 1 and

HYDRANT PRESSURE indicated while Stream is flowing by Gauge attached to Hydrant, as shown. Lbs. per sq. in.	Quantity of Water Discharged per minute through ordinary 2½-inch Fire Hose, (United States Gallons of 231 cubic inches.) Open Hose Butt. No Play-								
	Length 25 feet.			Length 50 feet.			Length 100 feet.		
	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside Rough.	Ordinary best quality Rubber-lined Hose. Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside Rough.	Ordinary best quality Rubber-lined Hose. Inside Smooth.	Unlined Linen Hose.	Inferior Rubber-lined Cotton "Mill Hose." Inside Rough.	Ordinary best quality Rubber-lined Hose. Inside Smooth.
	If Hydrant were of Style A, discharge would be 5 per cent. greater.	If Hydrant were of Style A, discharge would be 5 per cent. greater.	If Hydrant were of Style A, discharge would be 9 per cent. greater.	If Hydrant were of Style A, discharge would be 3 per cent. greater.	If Hydrant were of Style A, discharge would be 3 per cent. greater.	If Hydrant were of Style A, discharge would be 6 per cent. greater.	If Hydrant were of Style A, discharge would be 1½ per cent. greater.		
10	231	242	297	176	188	242	132	140	188
15	283	297	363	217	230	297	161	171	230
20	326	343	419	251	266	343	186	199	266
25	365	383	468	281	297	383	208	222	297
30	400	420	514	307	326	420	228	243	326
35	432	453	554	332	352	453	246	262	352
40	462	484	593	355	376	484	264	280	376
45	490	514	630	377	399	514	280	297	399
50	516	542	664	398	420	542	294	313	420
55	541	568	696	416	440	568	308	328	440
60	565	594	726	434	460	594	322	343	460
65	588	618	756	452	480	618	336	358	480
70	610	641	784	470	498	641	348	371	498
75	632	663	812	486	515	663	360	384	515
80	652	685	....	502	532	685	372	397	532
85	672	706	....	518	548	706	383	409	548
90	692	727	....	533	564	727	394	421	564
95	712	747	....	547	579	747	405	432	579
100	730	766	....	561	594	766	416	443	594
110	766	806	....	588	623	806	436	465	623
120	800	....	....	614	651	....	456	486	651

TABLE B.—No. 3.
(From experiments of J. R. FREEMAN, 1888.)

TABLES.—"Open Hose Butts."

discharge through "Open Butt" is not nearly so great as may be obtained by the methods B. No. 2—by reason of greater influence of form of Hydrant and differences in Hose.

with Couplings of 2½-inch Bore. Pipe or Nozzle attached.

Length 200 feet.		Length 400 feet.	
Inferior Rubber-lined Cotton "Mill Hose." Inside Rough.	Ordinary best quality Rubber-lined Hose. Inside Smooth.	Inferior Rubber-lined Cotton "Mill Hose." Inside Rough.	Ordinary best quality Rubber-lined Hose. Inside Smooth.
102	140	74	102
125	171	90	125
144	199	104	144
161	222	116	161
177	243	127	177
190	262	137	190
204	280	146	204
217	297	155	217
228	313	164	228
239	328	172	239
250	343	179	250
260	358	186	260
270	371	194	270
279	384	201	279
288	397	208	288
297	409	215	297
306	421	221	306
314	432	227	314
322	443	232	322
338	465	243	338
354	486	254	354

NOTE.—The values in this table are based on experiments with these kinds of Hose attached to a Chapman 4-way Independent Gate Hydrant (Coeff. Disch. by Expt. 0.71). So far as influence of kind of Hydrant upon discharge is concerned, the same values are correct enough for practical purposes, except as noted in margin of columns.

It will be noted that this table gives, for each length, the discharge through the best or smoothest hose, and gives, also, discharge for same length of Hose with roughest waterway. By use of a little judgment in interpolating between these two values, error, in ordinary use of table need not exceed 10 per cent.

(Style A.) Ordinary Matthews (R. D. Wood & Co.'s) Hydrant without independent gates, inside corner being rounded off.

HOLYOKE HYDRANT TESTS.

Tables B, No. 4 and B, No. 5 for the discharge of open hydrant butts, and the values following, on the friction losses in hydrants (pages 58 and 59), were obtained from the Holyoke Hydrant Tests.

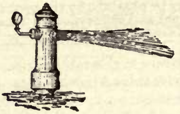
These tests were made in 1897 and 1898, for the Water Department of Holyoke, by Charles L. Newcomb, M. E., the Inspection Department of the Associated Factory Mutual Insurance Cos. co-operating in the work and in the computation of results. For full data on these experiments, see "Transactions of the American Society of Mechanical Engineers," vol. xx.

(If Gauge is not connected in this manner, proper allowance must be made for loss of pressure between Gauge and Hydrant.)

PUMP INSPECTION

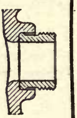
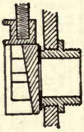
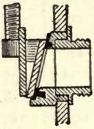
Discharge through One Open

Diameter of Outlet



If the diameter of outlet is not exactly $2\frac{1}{2}$ inches, an additional correction as follows must be made.

Diameter.	Add.	Deduct.
$2\frac{5}{8}$	10 per cent.	....
$2\frac{9}{16}$	5 "	....
$2\frac{7}{16}$	....	5 per cent.
$2\frac{3}{8}$	....	10 "
$2\frac{1}{4}$	....	19 "

HYDRANT PRESSURE	Chapman 2-Way.	Chapman 2-Way.	Chapman 2-Way.	Chapman 3-Way.	Chapman 3 or 4-Way.	Coffin 2-Way.
Indicated while Stream is flowing by Gauge attached to Hydrant, as shown.	"No. 1." Old pattern made from 1878–1899. Casting at outlets, square and jagged. Inside diam. of bbl. at outlets, $4\frac{3}{4}$ ins. * See Note page 44.	"No. 2." Same Hydrant as No. 1, but with outlets chipped and filed fairly smooth and rounding, but with short radius.	"No. 3." 2-Way with Steamer Connection. Pattern made after 1898. Casting at outlets smooth and well rounded. Inside diam. of bbl. at outlets, $7\frac{3}{4}$ ins.	Hexagonal Pattern, with Independent Gates, made after 1897. Outlets have sharp corners and project into bbl. Inside diam. of bbl. at outlets (hex'l), $6\frac{9}{16}$ ins † See Note p. 44.	Regular pattern of Independent Gate; also used as 3-Way, with one outlet blanked. Made since 1883. Outlets have sharp corners and project into bbl. Inside diam. of bbl. at outlets, $8\frac{1}{4}$ ins. † See Note p. 44.	Same discharge for 2-Way Gate & 2-Way Compression with Steamer Connection. Nozzle entrances have well rounded corners. Inside diam. of bbl. at outlets, 6 ins
						
Lbs. per sq. in.	Gals. per Min.	Gals. per Min.	Gals. per Min.	Gals. per Min.	Gals. per Min.	Gals per Min.
10	440	547	552	371	363	499
15	541	667	678	458	444	610
20	627	765	776	531	513	705
25	700	853	861	593	573	785
30	762	938	928	648	630	855
35	820	1,018	986	701	680	919
40	878	1,090	1,035	748	725	980
45	929	1,155	1,084	792	767	1,039
50	979	1,218	1,133	835	806	1,093
55	1,025	1,280	1,182	877	845	1,144
60	1,070	1,337	1,227	915	883	1,193
65	1,112	1,394	1,269	951	919	1,240
70	1,154	1,447	1,309	987	953	1,285
75	1,195	1,499	1,349	1,021	986	1,329
80	1,234	1,549	1,385	1,055	1,018	1,370
85	1,270	1,598	1,420	1,087	1,049	1,410
90	1,305	1,644	1,454	1,119	1,080	1,450
95	1,342	1,690	1,489	1,148	1,109	1,490
100	1,375	1,734	1,520	1,177	1,138	1,528

Use same values when no Steamer Connection.

Use same values for Ludlow 3, 4 and 6-Way.

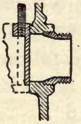
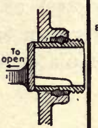
TABLES.—"Open Hydrant Butts."

TABLE B.—No. 4.
From Holyoke Hydrant Tests, see page 41.

Hydrant Butt, without Hose attached.

exactly 2½ ins.

The degree of accuracy attained in estimating the discharge through the "open butt" is not nearly so great as may be obtained by the methods of the three preceding tables, — B, Nos. 1, 2, and 2A. Slight peculiarities in the construction of the nozzle, and possibly also in the shape of the hydrant head, make large differences in the discharge from the open butt without hose. The data below covers the types of outlets usually found and, with good judgment in applying corrections for hydrants not exactly coming under any of the cases given, results accurate within 10 to 15 per cent. may generally be obtained.

Holyoke 2-Way.	Holyoke 6-Way.	Ludlow 2-Way.	Mathews 2-Way.	Mathews 4-Way.	HYDRANT PRESSURE
Regular Pattern Gate or Compression. Casting at outlets well rounded but rough with nubs and projections. Average of 4 Hydrants.	Independent Gates. Outlets have sharp corners. Diam. of outlet hole in casting, 3¼ ins. Nipple tapers to 2½ ins. Inside diam. of bbl. at outlets 9¼ ins.	Regular Patt'rn. Diam. of outlet hole in casting, 2¾ to 3 ins. and square & jagged. Corners of 2½-in. nipple are sharp. Inside diam. of bbl. at outlets, 7¼ ins. See Note p. 45.	2-Way with Steamer Connection. Casting rounded at outlets to radius of abt. ¼ in. Inside diam. of bbl. at outlets, 7⅛ ins.	Independent Gates. When open, distance from valve face to outlet is 1⅛ to 1¼ in. Outlets have sharp corners. Inside diam. of bbl. at outlets, 8½ ins.	indicated while Stream is flowing by Gauge attached to Hydrant as shown.
					
Gals. per Min.	Gals. per Min. (Use same values for 3 and 4 Ways.)	Gals. per Min.	Gals. per Min. (Use same values when no Steamer Connection.)	Gals. per Min.	Lbs. per sq. in.
506	473	533	576	465	10
620	579	653	712	565	15
713	668	752	815	633	20
794	743	836	903	683	25
867	805	912	984	724	30
935	860	982	1,060	762	35
999	908	1,049	1,130	796	40
1,062	954	1,109	1,197	827	45
1,118	999	1,169	1,257	858	50
1,170	1,044	1,223	1,314	889	55
1,221	1,089	1,276	1,370	919	60
1,270	1,129	1,328	1,423	944	65
1,318	1,168	1,376	1,474	969	70
1,363	1,204	1,421	1,524	994	75
1,408	1,240	1,467	1,572	1,015	80
1,449	1,275	1,510	1,619	1,037	85
1,490	1,309	1,553	1,663	1,058	90
1,530	1,340	1,595	1,705	1,079	95
1,569	1,370	1,638	1,747	1,098	100

For further descriptions of hydrants and friction losses in them see pages 58 and 59.

NATIONAL BOARD SPRINKLER RULES.

SECTION M—PRESSURE TANK.

1. *Capacity.*—Total capacity of tank to be specified by Underwriters having jurisdiction, but not less than 4,500 gallons, except by special permission.

2. *Location.*—Tank not to be located below upper story of building.

3. *Tank Service.*—Tanks to be used as a supply to automatic sprinklers and hand hose only. (See Sec. T, 1 and 10.)

4. *Construction.*—(a) *Material.*—To be of fire box or flange steel of even quality, having a tensile strength of not less than 55,000, nor more than 60,000 pounds. Thickness of plates to be determined by the following formula:

$$T = \frac{P \times r \times 6}{.75 \times S}$$

T = Thickness of plate in inches.
P = Working pressure in pounds per square inch.
r = Internal radius of shell.
S = Tensile strength of plates in pounds per square in.
6 = Factor of safety.
.75 = Value of riveted joints.

(b) *Heads.*—To be $\frac{1}{8}$ inch thicker than shell where the diameter of the tank is 84 inches or less and at least $\frac{1}{4}$ inch thicker where the diameter is in excess of 84 inches.

Radius of dish to be equal to the diameter of the tank.

(c) *Seams.*—Longitudinal seams to be triple riveted and placed below the water line. Girth seams to be single riveted except where the diameter of the tank is in excess

of 84 inches, when double riveting should be employed. Riveting to be done in a careful and thoroughly workmanlike manner. All seams to be thoroughly caulked inside and out.

(d) *Manhole.*—To be large enough to allow easy access to the inside of the tank and placed below the water line.

(e) *Outlet.*—Discharge nozzle to be placed in the bottom of the tank and fitted with 1½-inch side outlet threaded for filling and draining connections. Inlet for air connection to be 1 inch and placed at proper point for upper gage glass nipple, where suitable connections may be made for both purposes.

5. *Test.*—Tank to be tested and proved tight at a hydrostatic pressure of at least 25 per cent. in excess of the normal working pressure required. Water then to be drawn off to the two-thirds line and tank tested at the working air pressure required. In this condition and with all valves closed, tank not to show loss of pressure in excess of ½ pound in 24 hours.

6. *Fittings and Connections.*—(a) *Gage Glass.*—To be placed on the end of horizontal and side of upright tank so that the two-thirds line will be at the center of the glass. Gage glass valves to be of the best quality angle globe pattern.

NOTE.—The two valves in the water gage connections to be kept closed and opened only to ascertain the amount of water in the tank, as breaking of or leakage about glass will cause the escape of pressure.

(b) *Pressure Gage.*—To be placed directly on the upper gage glass nipple and provided with a separate shut-off valve.

(c) *Filling Point.*—Tank to be kept two-thirds (⅔) full of water and have a fixed metallic horizontal line opposite gage glass, indicating this water level. A conspicuous

sign indicating minimum air pressure allowed to be stamped on the fixed metallic plate indicating the water level.

NOTE.—For horizontal tanks the two-thirds line to be determined by the following formula: Distance above the bottom equals 1.265 × radius of tank in inches.

(d) *Filling Pipe.*—Water for supplying tank to be conveyed through fixed iron piping not less than 1½-inch in size. Sprinkler piping not to be used for this purpose. Pipe from air pump to tank to be not smaller than 1 inch; to be independent of water supply pipe; to connect with tank above the water level. Both water and air connections to be fitted with check and stop valves located near tank.

(e) *Drain Pipe.*—Provision to be made to drain each tank independently of other tanks and the sprinkler system.

7. *Pressure.*—When the tank is located on a level with the highest sprinklers an air pressure not less than 75 pounds should be maintained in order that a pressure of not less than 15 pounds will be furnished at the highest line of sprinklers when all water has been discharged from the tank.

When the tank is located lower than the highest sprinklers a pressure in excess of 75 pounds should be maintained. This excess pressure to be equal to three times the pressure, due to the height of the sprinklers above the tank.

8. *Pump for Filling.*—It is desirable to have water fed to tank by a pump so that proper water level may be restored at any time without reducing air pressure.

9. *Air Compressor.*—A steam or electrically driven air compressor having sufficient capacity to increase the air pressure at an average rate of at least 1 pound in two minutes should be provided.

NOTE.—Where the compressor is also used to maintain dry pipe systems, the air supply should be taken from outside or from a room having dry air, in order to avoid carrying moisture into the pipe system. The intake should be protected by a screen.

10. *Tank House.*—Tank to be properly protected from frost, and if located above the roof to be enclosed in a house of substantial construction and of ample size to provide free access on all sides.

Space to be at least 3 feet at end where gages are located and window to be provided opposite gages.

Tank house to be constructed in accordance with the requirements of municipal or building authorities where they exist.

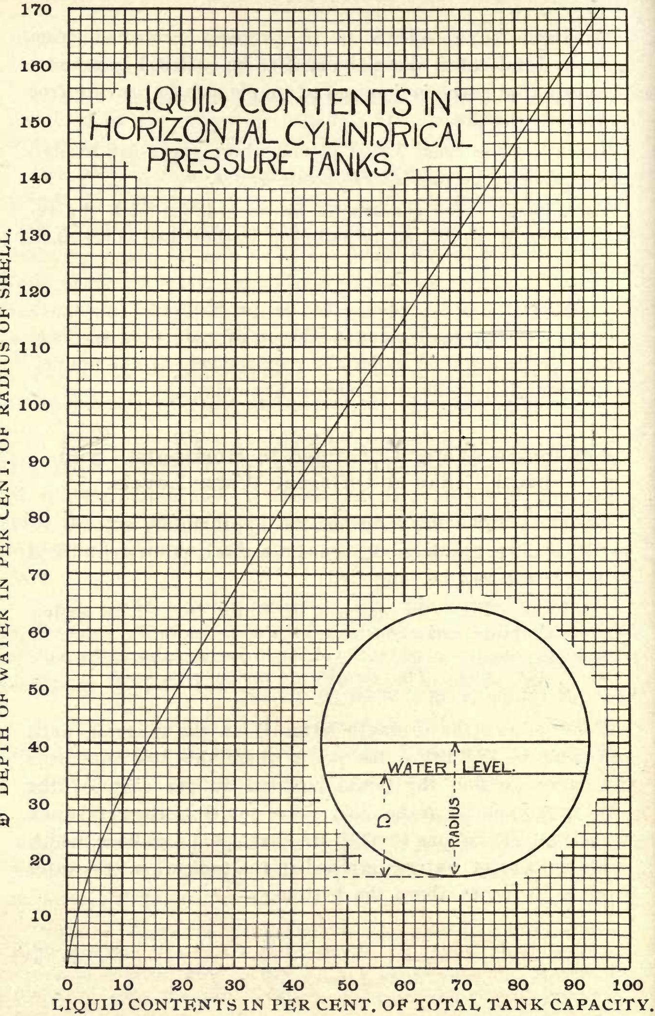
11. *Supports for Tanks.*—To be proportioned so as to safely carry the load using a factor of safety of at least four. To be installed under the requirements of the municipal or building authorities where they exist.

Amount of Water Contained in Horizontal Cylindrical Tanks at Different Water Levels.

From the following diagram the approximate amount of water at any depth contained in a horizontal cylindrical pressure tank can be computed:

EXAMPLE.—Find the amount of water in a 4,500-gallon horizontal cylindrical pressure tank, 72 inches in diameter, 22 feet long, when the water level is 26 inches above the bottom of the tank. The depth of water expressed in per cent. of radius is $26 \div 36 = .72$.

Follow down the ordinate letter D on the diagram until you come to 72; below the point where this line intersects the curve we find the liquid contents in per cent. of the total tank capacity to be .327. Now multiply the total tank capacity 4,500 gallons by .327, we have 1,471.5 gallons, which is the amount of water contained in the tank when the water level is 26 inches above the bottom.



CURVE SHEET No. 3. FIG. No. 23.

PRESSURE TANK FOR SPRINKLER SYSTEM.

For end view see Fig. 43.

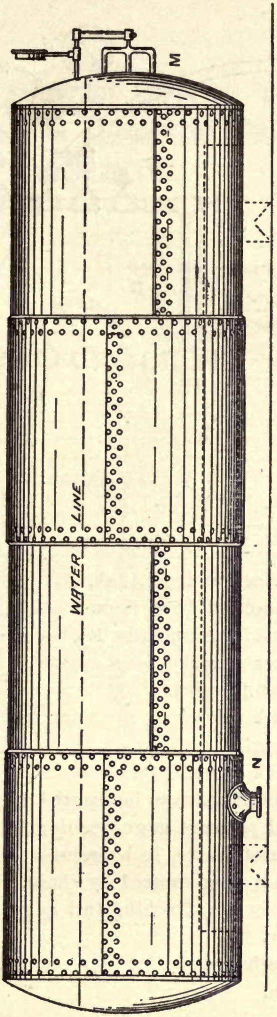


FIG. 42A.

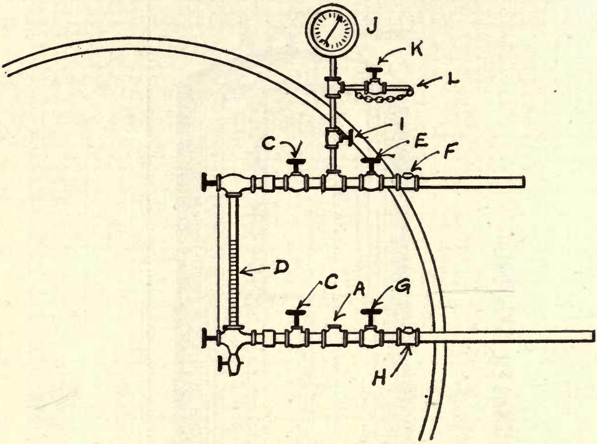


FIG. 43

NOTATION.

A 1¼ inch connection from tank.
B ¾ inch connection from tank.
C ¾ inch Shutoff valve, to be kept closed.
D ¾ inch water gage.
E ¾ inch Shutoff valve.
F ¾ inch check valve.
G ¾ inch Shutoff.
H ¾ inch check valve.
I ¾ inch Shutoff valve to be secured open.
J 5 inch dial pressure gage, reading to 150 lbs.
K ½ inch Shutoff valve, to be secured closed.
L ½ inch brass plug secured by chain.
Opening is for attaching test gage.
M Man hole.
N 4 inch discharge outlet for connection to sprinkler system.

TYPICAL ARRANGEMENT OF SUPPLIES, CONNECTIONS AND VALVES FOR AUTOMATIC SPRINKLER EQUIPMENTS.

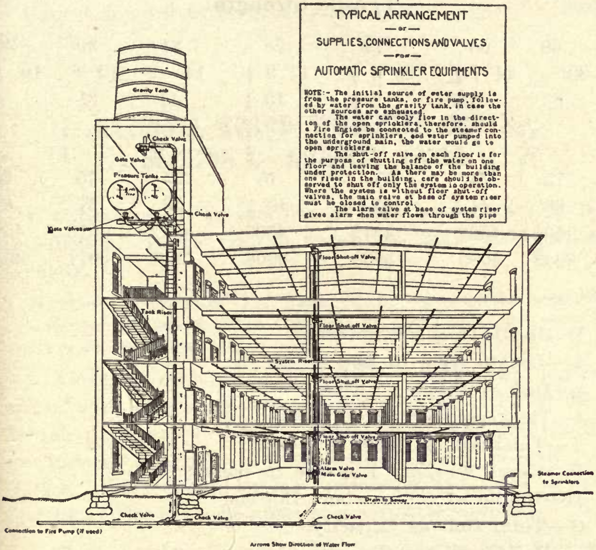


FIG. 42

SPECIFICATIONS FOR STANDARD PRESSURE TANKS.

SUITABLE FOR USE IN CONNECTION WITH AUTOMATIC SPRINKLER EQUIPMENTS.

THE CHICAGO UNDERWRITERS' ASSOCIATION.

Material—Open Hearth Tank Steel; 60,000 Pounds Tensile Strength.

D—	60	66	72	78	84	90	96
L—	30′	24′ 7 $\frac{1}{4}$″	20′ 6 $\frac{1}{2}$″	17′ 3 $\frac{3}{4}$″	14′ 9″	12′ 8″	10′ 11″
r—	8	8 $\frac{3}{4}$	9 $\frac{1}{2}$	10 $\frac{1}{4}$	11	12	13
t—	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$
T—	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$
P—	75	75	75	75	75	75	75
H—	38″	41 $\frac{3}{4}$″	45 $\frac{3}{4}$″	49 $\frac{1}{2}$″	53	57	61
G—	4505	4502	4512	4509	4512	4516	4512
g—	3003	3000	3008	3006	3008	3011	3009

Where

D—Inside Diameter in inches.
L—Length, End to End of Sheets.
r—Dish of Heads in inches.
t—Thickness of Shell in inches.
T—Thickness of Heads in inches.
P—Usual Working Pressure in pounds.
H—Height of $\frac{2}{3}$ Line above Bottom.
G—Total Gallons Capacity.
g—Gallons Water Capacity.

Heads.—Radius of dish to be equal to diameter of shell.

Seams.—Longitudinal seams to be triple riveted and placed below the water line. Girth seams to be single riveted except in the 90 and 96 inch diameters, which should be double riveted. All riveting to be either hand or machine work; snap riveting not recommended.

Manhole.—To be placed in the shell below the water line.

Openings.—Discharge nozle to be 6-inch, placed in bottom of tank, with 1½-inch inside outlet threaded for filling and drain connection. Inlet for air connection to be 1¼-inch and placed on top of tank.

Gage Glass.—To be placed on end of horizontal tank, and side of upright tank so that two-thirds line will be at center of glass.

Gage Glass valves to be of angle pattern equal to Crane No. 522.

NATIONAL BOARD SPRINKLER RULES.
SECTION I.—GRAVITY TANK.

1. *Capacity.*—To be specified by the Underwriters having jurisdiction. In no case to be of less than 5,000 gallons capacity.

NOTE.—Capacity of the tank to be computed from the net depth measured from the top of the discharge pipe to bottom of overflow pipe.

2. *Elevation.*—Elevation of bottom of tank above highest line of sprinklers on system which it supplies to be specified by the Underwriters having jurisdiction. The greater the elevation of a gravity tank the less likelihood of inefficient service. Underwriters having jurisdiction are urged to have such tanks placed at the greatest practicable elevation.

3. *Tank Service.*—Tank to be used as a supply to automatic sprinkler system only, except that, at the discretion of the Underwriters, tank may be made larger than called for, and so arranged that the excess supply only may be used for other purposes.

4. *Independent Drain.*—Provision to be made to drain each tank independently of other tanks and the sprinkler system. The practice of placing drain valves at lower levels and accessible from the exterior of buildings is not approved.

5. *Construction of Wooden Tanks.*—(a) *Material:* To be of cedar, cypress or white pine, of good quality, thoroughly air dried. Staves and bottom to be 2½-inch (dressed to not less than 2¼-inch) for tanks not exceeding 16 feet diameter and 16 feet deep, and for larger tanks 3-inch stock is to be used (dressed to not less than 2¾-inch). Taper of tank to be not less than ½ inch per foot and not more than 1 inch.

NOTE.—The tank should be filled with water immediately on erection, and contracts should include erection and frost casing of the discharge pipe.

(b) *Hoops.*—To be of round wrought iron or mild steel of good quality and without welds and thoroughly painted before and after erection of tank. (Wrought iron is preferable, as it does not rust so easily.) No hoop less than ¾ inch in diameter to be used and spacing between hoops never to exceed 21 inches. To be of such size and so spaced that in no hoop will the stress exceed 12,500 pounds per square inch, area computed at the base of the thread. After determining size of hoops to be used they are to be spaced by the following formula:

$$\text{Spacing of hoops (in inches)} = \frac{\text{Safe load for given hoop in lbs.}}{2.6 \times \text{dia. (ft.)} \times \text{depth (ft.)}}$$

The lugs are to be as strong as the hoop iron and preferably of malleable iron, but if cast iron, to be extra heavy.

NOTE.—In the above formula "depth" refers to the distance from the overflow to the point where the hoop is to be located.

(c) *Supports for Tank.*—To be proportioned so as to safely carry the load, using four as a factor of safety. They are to be installed under requirements of the municipal or building authorities where they exist. Planks upon which the bottom rests to be not over 18 inches apart and of such thickness that lower end of staves will be at least 1 inch from floor.

(d) *Cover.*—To be provided when the tank is exposed to the weather, to be double, with air space between covers, and upper one should preferably be conical in shape. A trap door to be provided in each cover.

(e) *Boxing for Piping.*—When exposed, discharge pipe to be protected by a double, triple or quadruple boxing as may be required. Steam pipe or pipes for heating tank to be placed next to the discharge pipe and installed so as to be free from woodwork.

NOTE.—No packing material or covering should be placed around pipes.

(f) *Ladders.*—A substantial, permanent ladder or stairway extending above top of tank sufficiently to provide easy access, to be provided.

NOTE.—The outside ladder at a tank exposed to the weather affords a treacherous foothold at best. For years after it is erected, it must be used by inspectors in all seasons and conditions of wind, temperature and storm. A ladder of much more than ordinary strength and durability is required and should be most securely attached. A heavy iron pipeladder, having diamond-shaped treads, is recommended.

6. *Fittings and Connections.*—(a) *Filling Pipe:* To be at least 1½ inches, to discharge above the top of water in tank or in cases where main check valve is at bottom of riser, through a check valve and connection back of main check valve.

NOTE.—When permitted by Underwriters having jurisdiction the filling pipe may be connected into tank riser above the main gate and check valve. Pipes so connected to be provided with a check valve close to the riser.

(b) *Discharge Pipe.*—To enter bottom of tank and project 4 inches up inside, and where its length is over 30 feet and exposed above ground or roof, as with tank on trestle, an expansion joint or the equivalent is required.

(c) *Overflow.*—To be not less than 2-inch, as near top of tank as possible, and arranged to discharge where it can be readily observed, but not so as to cause the accumulation of ice on the structure.

(d) *Heating.*—Where there is exposure to cold, tank to be provided with a steam coil inside and at the bottom. Coil to be made of brass or galvanized iron to prevent rusting and provided with a return pipe to the boiler room, or, tank to be provided with a direct steam pipe from boilers discharging into water near top and fitted with a check valve and perforated fitting to prevent siphoning.

NOTE.—When the coil and return pipe is used the check valve and perforated fitting are unnecessary. Care should be taken to see that proper drainage is secured in all steam connections for heating. See Rule 5, (e), for protection of piping.

(e) *Tell-Tale.*—A water level indicating device of approved design to be furnished when required by Underwriters having jurisdiction.

7. *Steel or Iron Tanks.*—When used, to be constructed in conformity with the requirements of Underwriters having jurisdiction.

AUTHOR'S NOTE.—It is recommended that the architect be consulted concerning the safety of walls before attempting to erect a tank upon them. Where it is possible, an independent structure to carry the tank is preferable, both as to safety of the tank and building in case of fire.

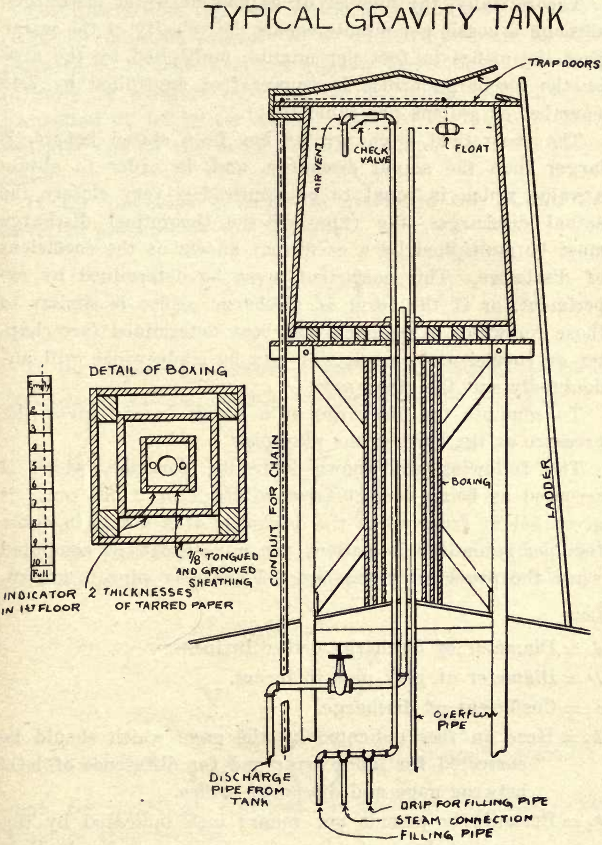

TYPICAL GRAVITY TANK
TRAP DOORS
CHECK VALVE
FLOAT
AIR VENT
DETAIL OF BOXING
CONDUIT FOR CHAIN
BOXING
LADDER
Empty
2
3
4
5
6
7
8
9
10
Full
7/8" TONGUED AND GROOVED SHEATHING
INDICATOR IN 1st FLOOR
2 THICKNESSES OF TARRED PAPER
OVERFLOW PIPE
DISCHARGE PIPE FROM TANK
DRIP FOR FILLING PIPE
STEAM CONNECTION
FILLING PIPE

FIG. 44

DISCHARGE OF NOZZLES.

Theoretically, the number of gallons of water discharged through a nozzle per minute equals the velocity of the water past the orifice in feet per minute, multiplied by the area oi the discharge orifice in square feet multiplied by 7.48 (number of gallons per cubic foot).

The theoretical discharge, as has been stated before, is larger than the actual discharge, and, in order to obtain a value which is equal to or approaches very closely the actual discharges, the value of the theoretical discharge must be multiplied by a coefficient known as the coefficient of discharge. This coefficient must be determined by experiment, or if the form of discharge orifice is similar to those for which a coefficient has been determined (see chapter on coefficients), a selection can be made which will undoubtedly suit the given case.

To compute the discharge of a nozzle having given the pressure at the base of the play pipe.

The following well-known hydraulic formulæ, which is accepted as being correct from within 1 or 2 per cent., is given below, from which the discharge of a nozzle in cubic feet per second or in gallons per minute can be computed when the pressure at the base of the play pipe is known.

Let

d = Diameter of discharge orifice in inches.

D = Diameter of play pipe in inches.

c = Coefficient of discharge.

h_1 = Head in feet indicated by the gage which should be corrected for index error and for difference of level between gage and discharge orifice.

p_1 = Pressure in pounds per square inch indicated by the gage at base of play pipe (corrected for level if necessary).

p = Effective pressure or static pressure at the base of the play pipe in pounds per square inch.

h =Effective head or static head at base of play pipe in feet.

The pressure at the base of the play pipe may be stated either as indicated pressure h_1 or effective pressure h. The pressure h_1 indicated by the gage is less than h the static pressure or pressure effective in producing discharge and projection of jet by an amount equal to the pressure theoretically due to the mean velocity of flow past the piezometer.

If the indicated pressure is given we can obtain the effective pressure by the formulæ

$$h = \frac{h_1}{1 - c^2\left(\frac{d}{D}\right)^4}$$

If the indicated pressure is given the discharge in cubic feet per second (Q) may be computed by the formulæ

$$(1) \qquad Q = \frac{.04374\, c\, d^2}{\sqrt{1 - c^2\left(\frac{d}{D}\right)^4}} \sqrt{h_1}$$

If the indicated pressure is given the discharge in gallons per minute (Q) may be computed by the formulæ

$$(2) \qquad G = \frac{29.83\, c\, d^2}{\sqrt{1 - c^2\left(\frac{d}{D}\right)^4}} \sqrt{p_1}$$

In many cases $\sqrt{1 - c^2\left(\frac{d}{D}\right)^4}$ is so nearly equal to 1 that for practical purposes it may be neglected. The formulæ then become

$$(3) \qquad Q = .04374\ c\ d^2 \sqrt{h}$$

$$(4) \qquad G = 29.83\ c\ d^2 \sqrt{p^1}$$

EXAMPLE.—How many gallons of water per minute will be discharged through a $1\frac{1}{2}$-inch smooth nozzle (similar to the Underwriters' play pipe) when the pressure at the base of the play pipe is 100 pounds.

For this type of nozzle we find the coefficient of discharge to be .976.

Substituting in equation 4 we have

$$G = 29.83 \times .976 \times 1.27 \times 100$$
$$= 29.83 \times .976 \times 1.27 \times 10$$
$$G = 373 \text{ gallons per minute—Ans.}$$

STANDARD UNDERWRITERS' PLAY PIPE.

Figure 45 shows a standard mill play pipe called the "Underwriters' Play Pipe," which was designed by John R. Freeman.

The throat of this pipe is larger than ordinary, being $1\frac{3}{4}$ inches in diameter. The nozzle is true taper with corner at end of taper rounded off on an easy curve. Straight part at end of taper is short. Washer at base of nozzle is placed outside to avoid any possible obstruction in the waterway, and is covered by a lip to prevent its being blown out. The body of the pipe is wound with cord for the purpose of affording a better grip, and rendering it more pleasant to handle in cold weather.

The play pipe is made of rolled brass pipe 1/16 of an inch thick or seamless drawn copper .05 inches thick. The waterway of the play pipe should be absolutely free from rough drops of solder or other projections and should have a smooth surface throughout. For best results, waterway should be smooth as a gun barrel. Inside of discharge orifice of tip should be straight for $\frac{3}{4}$ of an inch. End of tip should be extra heavy and cut out to prevent bruising. Inside taper of tip should be straight. All mountings to be of brass.

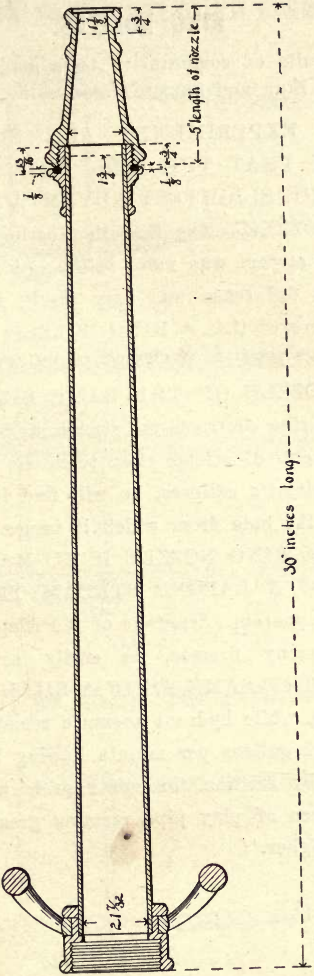


FIG. 45

RING NOZZLES.

In the results of comparative tests made by Mr. J. R. Freeman, on Ring and Smooth Nozzles, he states:

"THESE EXPERIMENTS ALL SHOWED CONCLUSIVELY THAT THE RING NOZZLE DOES NOT POSSESS THE SLIGHTEST ADVANTAGE OVER THE SMOOTH NOZZLE. The Smooth Nozzle proved slightly superior; its stream was more solid, and reached a little further; this difference was very small, however. Other experiments proved that A RING NOZZLE DISCHARGES ONLY $\frac{3}{4}$ AS MUCH WATER PER MINUTE AS A SMOOTH NOZZLE OF THE SAME SIZE. The sharp corner of the ring contracts the stream, and if any one will measure diameter of stream close to nozzle with a pair of common machinist's calipers, he will find it about $\frac{1}{8}$ inch smaller than the hole from which it issues. THE ONLY USE OF THE RING NOZZLE IS TO MAKE A SHOW OF PLAYING A LARGER STREAM THAN IS THE FACT. The apparent advantage of the Ring Nozzle, which has misled many firemen, is easily explained. THE RESULT IS THE SAME AS IF A SMALLER NOZZLE WERE USED, while hydrant pressure remained the same. The number of gallons per minute flowing being less, the pressure lost by friction through hose is less; therefore, pressure at base of play pipe remains greater, therefore, stream goes higher."

SMOOTH NOZZLE STANDARD FORM.

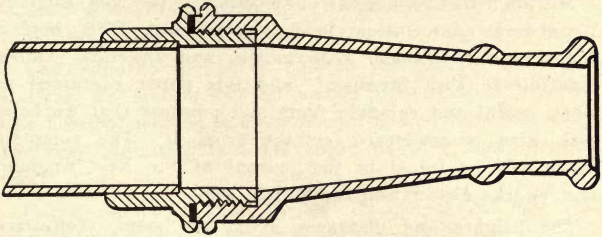


FIG. 46

ORDINARY SQUARE RING NOZZLE.

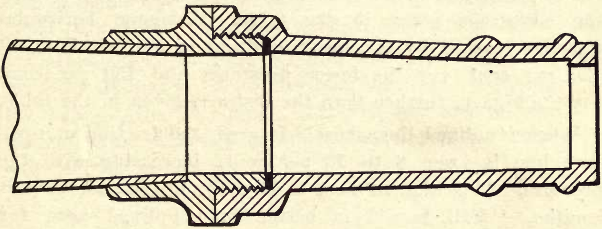


FIG. 47

UNDERCUT OR KNIFE EDGE RING NOZZLE.

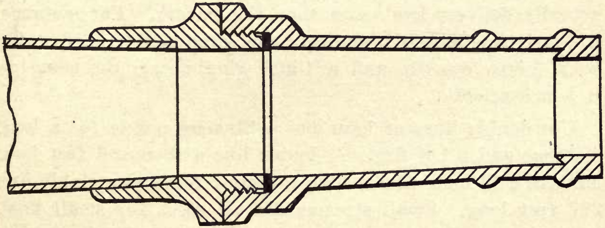


FIG. 48

FIRE STREAMS.

Mr. John R. Freeman, at the meeting of the New England Waterworks Association, held in December, 1889, read a paper entitled "Some Experiments and Practical Tables Relating to Fire Streams," and this paper contained so many useful and valuable facts and pointers that we herewith give a condensed extract from it. The complete paper will be found in the journal of the New England Waterworks Association for March, 1890.

The heights and distances given for good, "effective fire streams" are with moderate wind.

The maximum vertical height reached by the spray or drops in still air is from 22 per cent. for the lower pressures, to 56 per cent. for the higher pressures, higher than the elevations given in the table. Maximum horizontal distance reached by the spray or drops in still air is about 120 per cent. for the lower pressures and 150 per cent. for the higher, further than the distance given in the table.

When "unlined linen hose" is used, the friction or pressure loss is from 8 to 50 per cent., increasing with the pressure. This kind of hose is best for inside use in short lengths. "Mill hose" is better than unlined hose for long lengths, but the ordinary best quality, smooth, rubber-lined hose is superior to the "mill hose," having less frictional resistance.

The "ring nozzle" is inferior to the smooth nozzle and actually delivers less water than the smooth. For instance, a $\frac{7}{8}$-inch ring nozzle discharges the same quantity of water as a $\frac{3}{4}$-inch smooth, and a 1-inch ring nozzle the same as a $\frac{7}{8}$-inch smooth.

Use double lines of hose and a Siamese nozzle for a long distance and a hot fire. A double line a thousand feet long delivers a $1\frac{1}{4}$-inch stream with the same force as a single line 287 feet long. Small streams are all right for small fires, but with large, hot fires use a $1\frac{1}{4}$-inch or a $1\frac{3}{4}$-inch stream.

Such a stream will always make a black mark wherever it hits, and the stream which hits and cools the burning coals is the "effective fire stream." Small streams are converted into steam before touching the coals.

Two hundred and fifty gallons per minute is a good standard fire stream with 80 pounds pressure at the hydrant. One hundred pounds pressure should not be exceeded, except for very high buildings or length of hose exceeding 300 feet.

Curves shown in Figs. 27 and 28 (pages 281 and 282) give the discharge of hose nozzles through 50 and 100 feet of 2½-inch ordinary best quality of rubber-lined hose, and the head or pressure indicated at the hydrant.

Curves shown in Fig. 26 (page 280) show the pressure lost in pounds per square inch in 100 feet of cotton rubber-lined (smoothest lined) hose from 2 to 4 inches in diameter.

Curves shown in Figs. 24 and 25 (pages 278 and 279) give the discharge of nozzles and the head or pressure at the base of the play-pipe. Mr. Freeman states that with smooth, true, carefully calibrated nozzles very accurate results can be obtained.

FIRE STREAMS.

From Tables Published by John R. Freeman, M. E.

Press. at Nozzle	Gallons Disch. per Min.	Vert. Dist. of Stream	Hor. Dist. of Stream	Pressure in lbs. required at Hydrant or Pump to maintain pressure at nozzle through various lengths of 2½ inch smooth, rubber-lined hose.								
				50 Ft.	100 Ft.	200 Ft.	300 Ft.	400 Ft.	500 Ft.	600 Ft.	800 Ft.	1000 Ft.
¾ INCH SMOOTH NOZZLE.												
35	97	55	41	37	38	40	42	44	46	48	53	57
40	104	60	44	42	43	46	48	50	53	55	60	65
45	110	64	47	47	48	51	54	57	59	62	68	73
50	116	67	50	52	54	57	60	63	66	69	75	81
55	122	70	52	58	59	63	66	69	73	76	83	89
60	127	72	54	63	65	68	72	76	79	83	90	97
65	132	74	56	68	70	74	78	82	86	90	98	106
70	137	76	58	73	75	80	84	88	92	97	105	114
75	142	78	60	79	81	85	90	94	99	104	113	122
80	147	79	62	84	86	91	96	101	106	111	120	130
85	151	80	64	89	92	97	102	107	112	117	128	138
90	156	81	65	94	97	102	108	113	119	124	135	146
95	160	82	66	99	102	108	114	120	125	131	143	154
100	164	83	68	105	108	114	120	126	132	138	150	163
7-8 INCH SMOOTH NOZZLE.												
35	133	56	46	38	40	44	48	52	56	60	68	76
40	142	62	49	43	46	50	55	59	64	68	78	87
45	150	67	52	49	51	57	62	67	72	77	87	97
50	159	71	55	54	57	63	69	74	80	86	97	108
55	166	74	58	60	63	69	75	82	88	94	107	119
60	174	77	61	65	69	75	82	89	96	103	116	130
65	181	79	64	71	74	82	89	96	104	111	126	141
70	188	81	66	76	80	88	96	104	112	120	136	152
75	194	83	68	82	86	94	103	111	120	128	145	162
80	201	85	70	87	91	101	110	119	128	137	155	173
85	207	87	72	92	97	107	116	126	136	145	165	184
90	213	88	74	98	103	113	123	134	144	154	174	195
95	219	89	75	103	109	119	130	141	152	163	184	206
100	224	90	76	109	114	126	137	148	160	171	194	216

FIRE STREAMS—Cont.

From Tables Published by John R. Freeman, M. E.

Press. at Nozzle	Gallons Disch. per Min.	Vert. Dist. of Stream	Hor. Dist. of Stream	Pressure in lbs. required at Hydrant or Pump to maintain pressure at nozzle through various lengths of 2½ inch smooth, rubber-lined hose.								
				50 Ft.	100 Ft.	200 Ft.	300 Ft.	400 Ft.	500 Ft.	600 Ft.	800 Ft.	1000 Ft.
1 INCH SMOOTH NOZZLE.												
35	174	58	51	40	44	51	57	64	71	78	92	105
40	186	64	55	46	50	58	66	73	81	89	105	120
45	198	69	58	52	56	65	74	83	91	100	118	135
50	208	73	61	57	62	72	82	92	102	111	131	151
55	218	76	64	63	69	79	90	101	112	122	144	166
60	228	79	67	69	75	87	98	110	122	134	157	181
65	237	82	70	75	81	94	107	119	132	145	170	196
70	246	85	72	80	87	101	115	128	142	156	183	211
75	255	87	74	86	94	108	123	138	152	167	196	226
80	263	89	76	92	100	115	131	147	162	178	209	241
85	274	91	78	98	106	123	139	156	173	189	222	...
90	279	92	80	103	112	130	147	165	183	200	236	...
95	287	94	82	109	118	137	156	174	193	211	249	...
100	295	96	83	115	125	144	164	183	203	223	...	...
1⅛ INCH SMOOTH NOZZLE.												
35	222	59	54	43	49	60	71	82	94	105	127	149
40	238	65	59	50	56	69	81	94	107	120	145	171
45	252	70	63	56	63	77	92	106	120	135	163	192
50	266	75	66	62	70	86	102	118	134	150	181	213
55	279	80	69	68	77	95	112	130	147	165	200	235
60	291	83	72	74	84	103	122	141	160	180	218	256
65	303	86	75	81	91	112	132	153	174	195	236	...
70	314	88	77	87	98	120	143	165	187	209	254	...
75	325	90	79	93	105	129	153	177	201	224	...	...
80	336	92	81	99	112	138	163	188	214	239	...	...
85	346	94	83	106	119	146	173	200	227	254	...	...
90	356	96	85	112	126	155	183	212	241	...	...	...
95	366	98	87	118	133	163	194	224	254	...	...	...
100	376	99	89	124.	140	172	204	236	...	...	...	...

FIRE STREAMS—Cont.

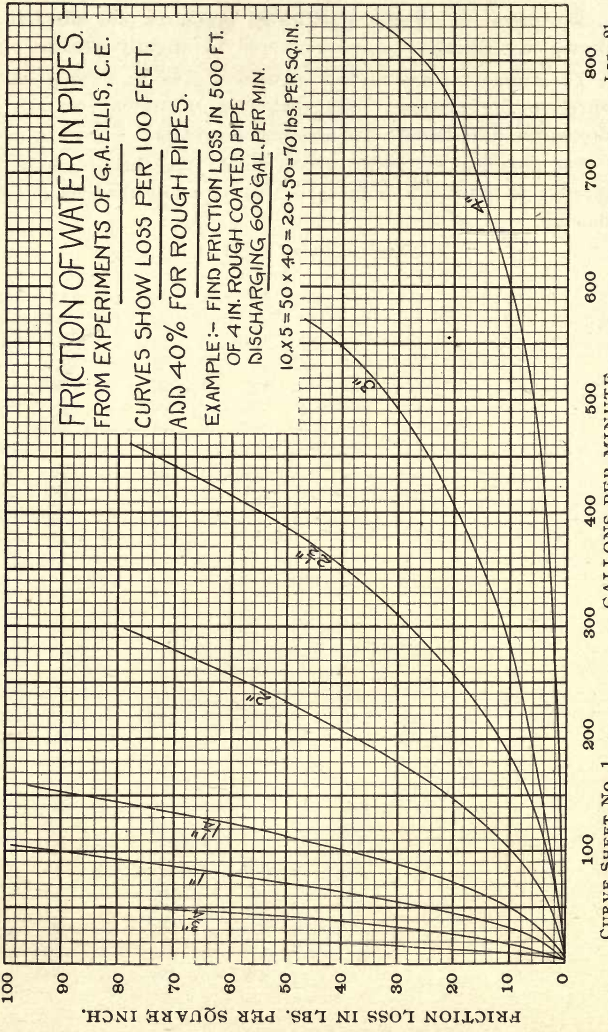
From Tables Published by John R. Freeman, M. E.

Press. at Nozzle	Gallons Disch. per Min.	Vert. Dist. of Stream	Hor. Dist. of Stream	Pressure in lbs. required at Hydrant or Pump to maintain pressure at nozzle through various lengths of 2½ inch smooth, rubber-lined hose.								
				50 Ft.	100 Ft.	200 Ft.	300 Ft.	400 Ft.	500 Ft.	600 Ft.	800 Ft.	1000 Ft.
1¼ INCH SMOOTH NOZZLE.												
35	277	60	59	48	57	74	91	109	126	142	178	212
40	296	67	63	55	65	84	104	124	144	164	203	243
45	314	72	67	62	73	95	117	140	162	184	229	...
50	331	77	70	68	81	106	130	155	180	204	254	...
55	347	81	73	75	89	116	143	170	198	225	...	...
60	363	85	76	82	97	127	156	186	216	245	...	...
65	377	88	79	89	105	137	169	201	234	...	...	...
70	392	91	81	96	113	148	182	217	252	...	...	...
75	405	93	83	103	121	158	195	232	...	...	...	...
80	419	95	85	110	129	169	208	248	...	...	...	...
85	432	97	88	116	137	179	221	...	...	...	...	...
90	444	99	90	123	145	190	234	...	...	...	...	...
95	456	100	92	130	154	201	247	...	...	...	...	...
100	468	101	93	137	162	211	261	...	...	...	...	...
1⅜ INCH SMOOTH NOZZLE.												
35	340	62	62	54	67	94	120	146	172	198	250	...
40	363	69	66	62	77	107	137	166	196	226	...	...
45	385	74	70	70	87	120	154	187	221	254	...	...
50	406	79	73	78	96	134	171	208	245	...	...	...
55	426	83	76	86	106	147	188	229	270	...	...	...
60	445	87	79	93	116	160	205	250	...	...	...	...
65	463	90	82	101	125	174	222	...	...	...	...	...
70	480	92	84	109	135	187	239	...	...	...	...	...
75	487	95	86	117	145	201	256	...	...	...	...	...
80	514	97	88	124	154	214	...	...	...	...	...	...
85	529	99	90	132	164	227	...	...	...	...	...	...
90	545	100	92	140	173	240	...	...	...	...	...	...
95	560	101	94	148	183	254	...	...	...	...	...	...
100	574	103	96	156	193	...	...	...	...	...	...	...

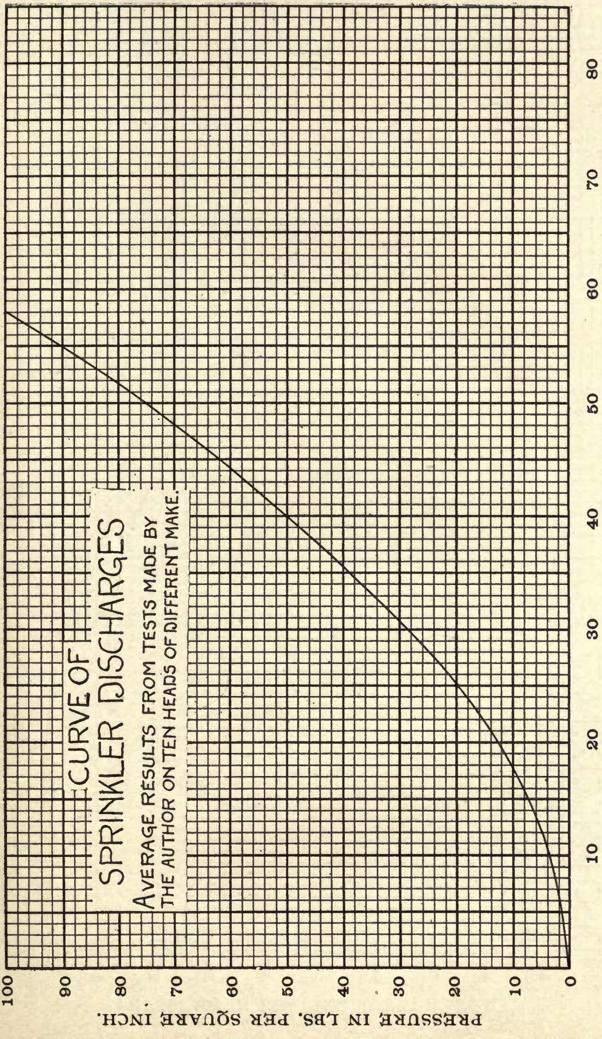
The pressures given are indicated pressures, not effective pressures. Effective pressures would be slightly greater.

The horizontal and vertical distances given are for good, effective fire streams. The distances to which insulated drops would be thrown are very much greater.

The pressures stated are based on the hose being coupled directly to the pump or the hydrant and while the stream is flowing.

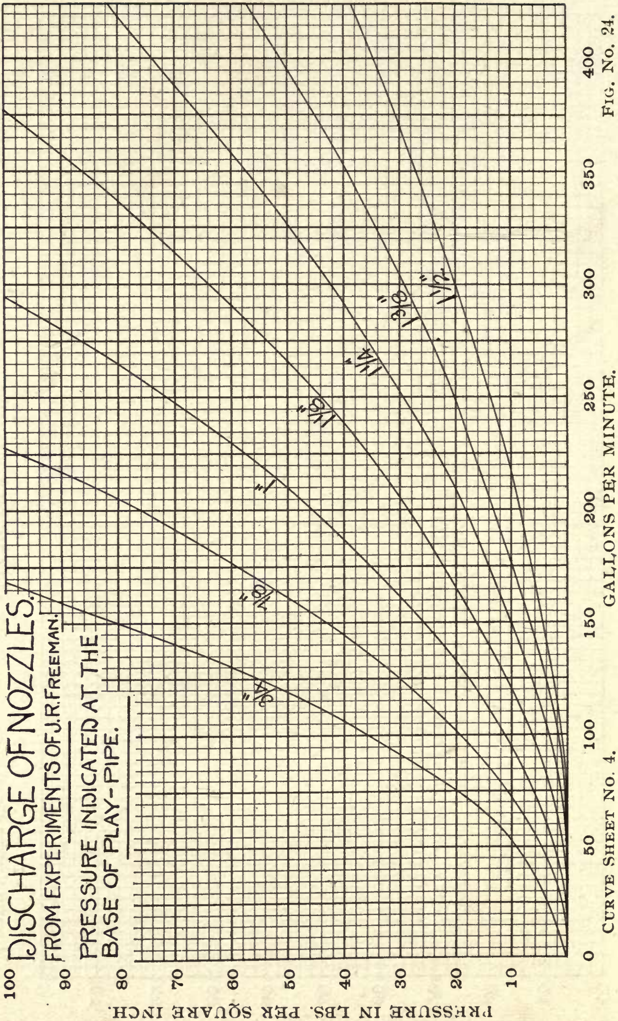


CURVE SHEET No. 1. FIG. 21.

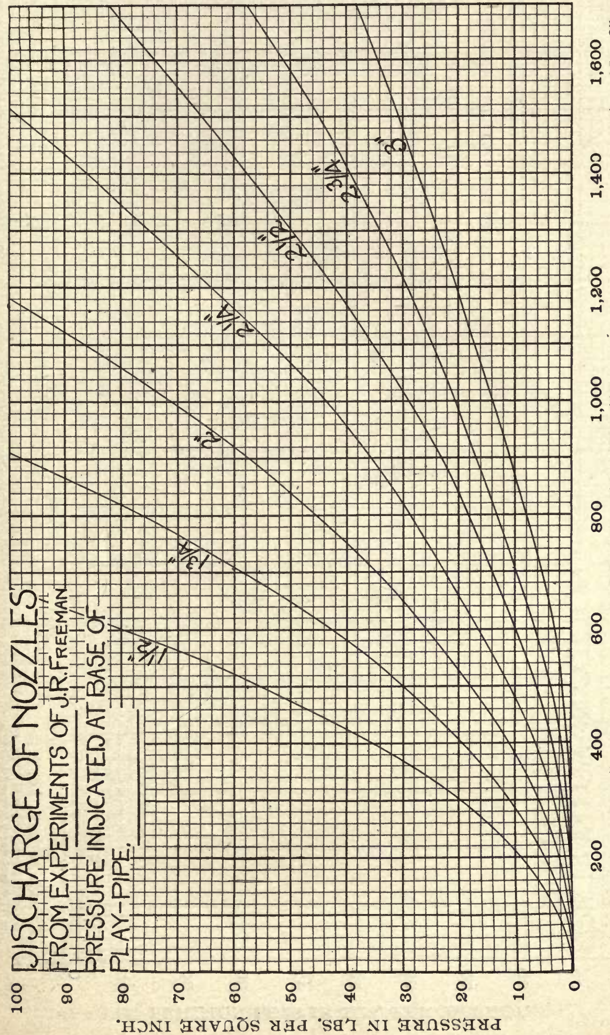


CURVE SHEET No. 2.

FIG. 22.

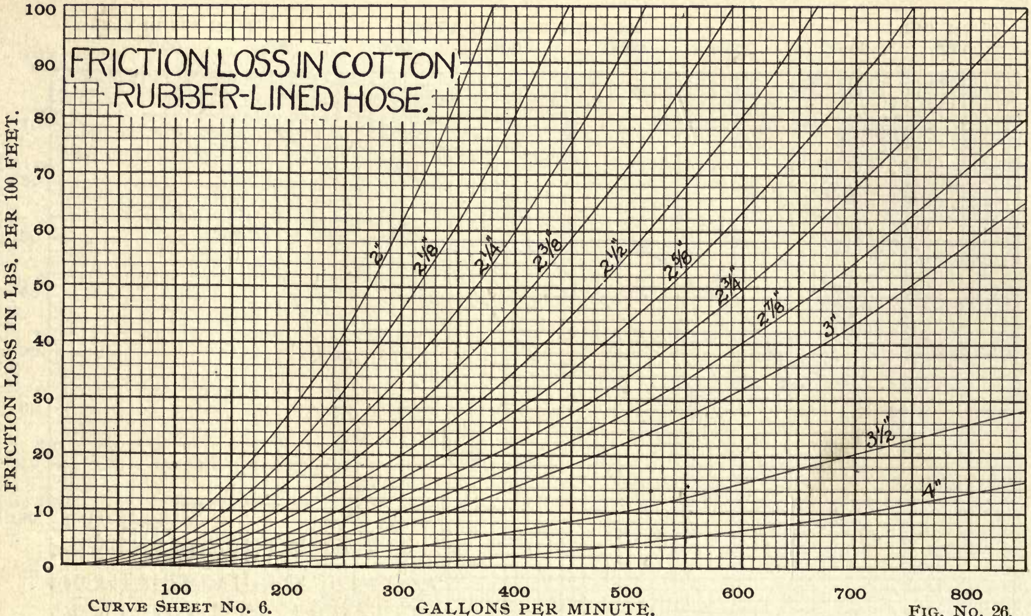


CURVE SHEET No. 4. FIG. No. 24.



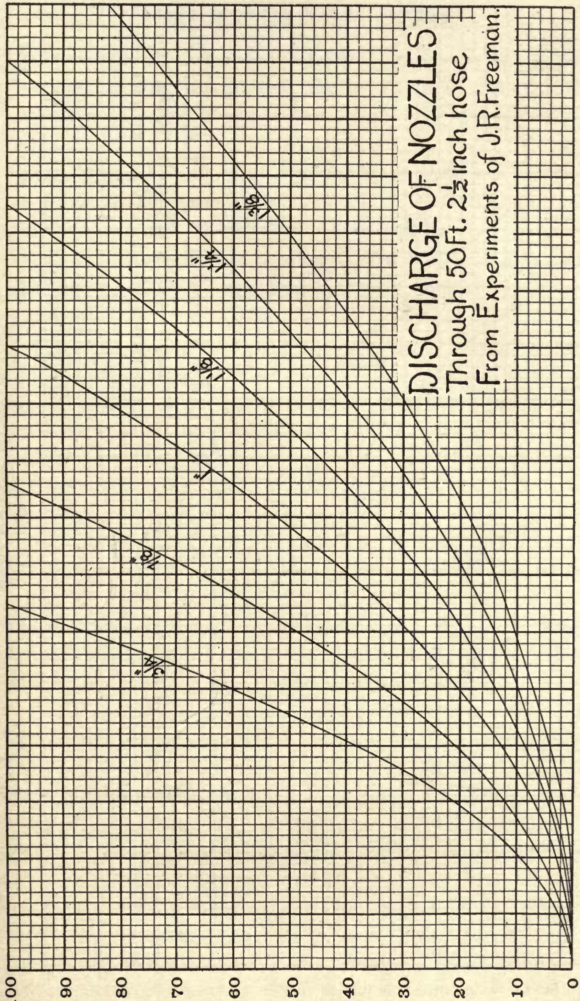
CURVE SHEET No. 5.

FIG. No. 25.

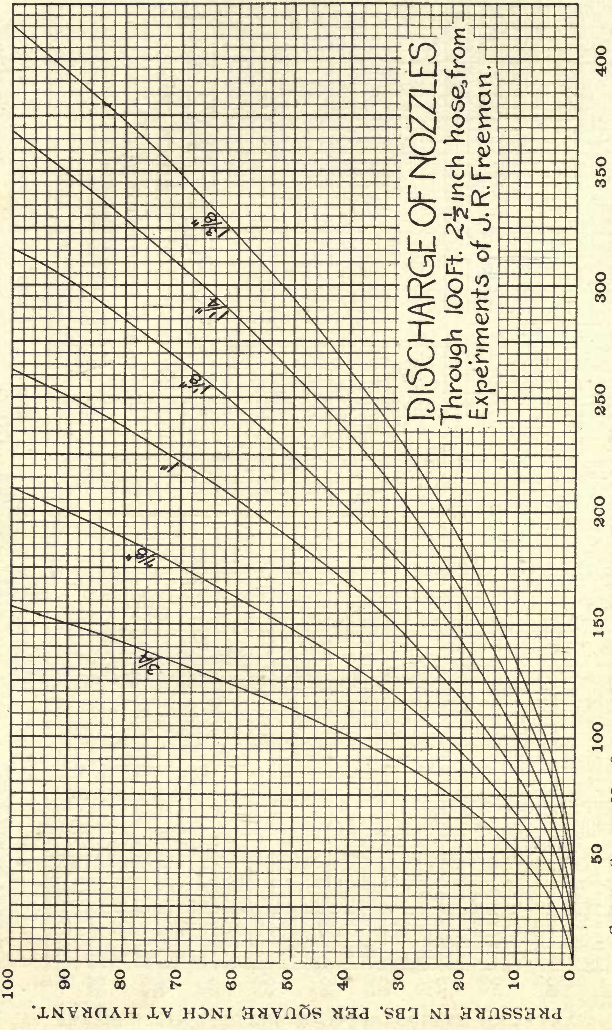


CURVE SHEET NO. 6. FIG. NO. 26.

NOTE.—For rough rubber lining, multiply loss by 2. For linen hose multiply loss by 2.3. These curves were computed on basis of 14 lbs. loss per 100 feet for 2½-inch hose, of the smoothest lining, with 250 gallons per minute flowing. The assumptions were made that, for a given diameter, the loss varies directly as the square of the quantity and for different diameters and same quantity, inversely as the 5th power of the diameters. For data in full see "Hydraulics of Fire Streams," by John R. Freeman, Transactions American Society of Civil Engineers, November, 1899.



CURVE SHEET No. 7. FIG. No. 27.



CURVE SHEET No. 8.

FIG. No. 28.

THE STEAM FIRE ENGINE.

The modern steam fire engine, practically a portable pumping engine, illustrates the remarkable concentration of power in small compass, with lightness and strength of parts.

As constructed by the best builders they are composed of selected materials, are exceedingly careful and well-proportioned and are beautifully finished.

The machine itself is composed of a boiler, engine, pump and the auxiliary appliances found necessary for its operation.

Their pumps have large passages and valves of small lift and deliver large volumes of water easily. The pumps are generally of the reciprocating or rotary type and are generally placed in front of the boiler. If of the reciprocating type, two pumps are placed alongside each other and are operated either by a double-slide valve or piston valve engine.

The piston rods of the engines connect directly with plunger rods of the pumps and are also connected to a crank shaft by means of either connecting rods or yokes, the cranks being set at right angles, so that one pump is always acting, while the other passes the ''dead'' center, which thus gives a practically steady stream.

Some of the engines are equipped with a boiler feed pump and others depend upon an injector or feed directly from the main pump. The engines exhaust into the stack, which gives the necessary draft.

The boilers, which are generally of the upright semi-water tube type, are combined with the engine by means of a strong iron frame, which carries all the auxiliary appliances and forms the body of the truck. The boilers contain little water and are crowded with heating surface; they therefore make steam with great rapidity, working pressure being generated in six to seven minutes from cold water.

The modern steam fire engines are generally classified as to size, and their capacities as follows:

Size of Engine.	Capacity gallons per minute.
Double Extra First	1,300
Extra First	1,100
First	900
Second	700
Third	600
Fourth	500
Fifth	400

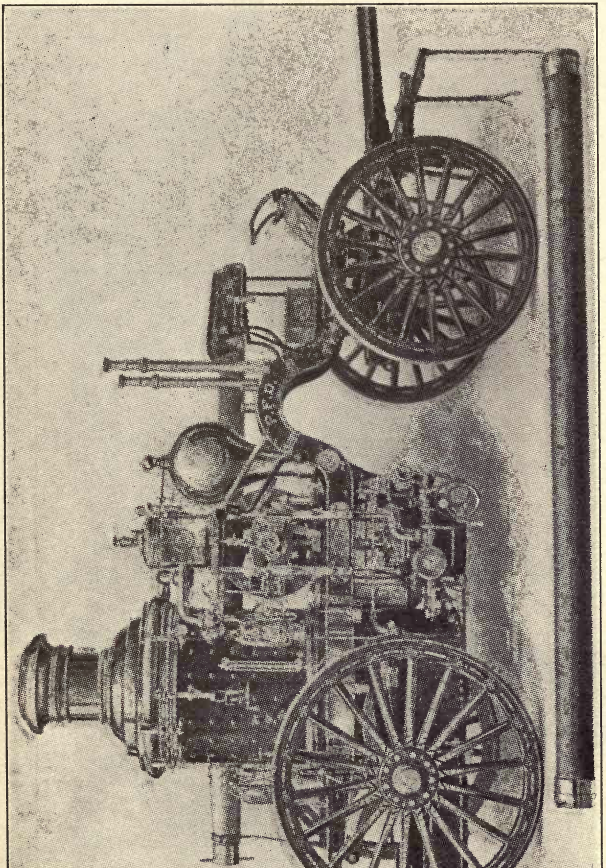


FIG. 49—METROPOLITAN STEAM FIRE ENGINE.
Manufactured by American La France Fire Engine Co., Elmira, N. Y.

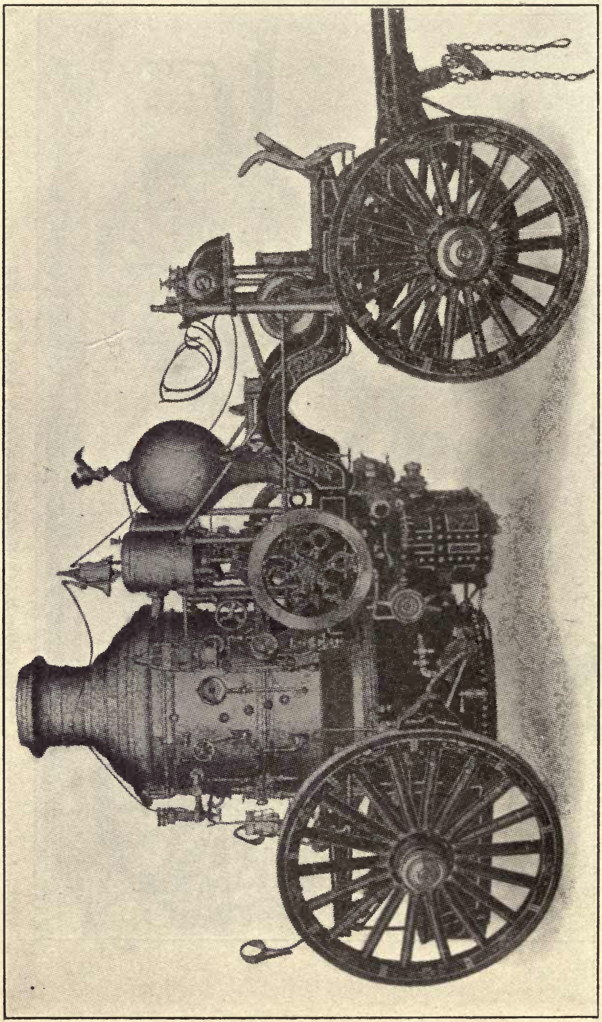


FIG. 50—THE LA FRANCE STEAM FIRE ENGINE (Double Extra First Size Piston Steam Fire Engine).
Manufactured by American La France Fire Engine Co., Elmira, N. Y.

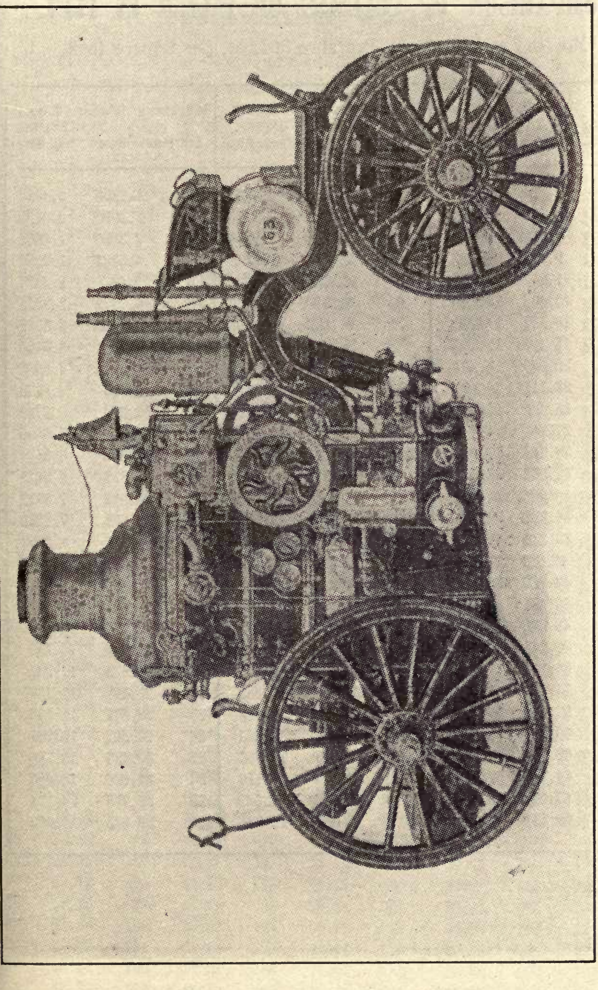


FIG. 51—THE NOTT STEAM FIRE ENGINE (Piston Valve Type).
Manufactured by Nott Fire Engine Co., Minneapolis, Minn.

COMPARISON OF COLUMNS OF WATER IN FEET.

Mercury in Inches and Pressure in Lbs., per Square Inch.

Lbs. Press. Sq. In.	Water Feet	Mercury Inches	Water Feet	Mercury Inches	Lbs. Press. Sq. In.	Mercury Inches	Water Feet	Lbs., Press Sq. In.
1	2.311	2.046	1	0.8853	0.4327	1	1.1295	0.4887
2	4.622	4.092	2	1.7706	0.8654	2	2.2590	0.9775
3	6.933	6.138	3	2.6560	1.2981	3	3.3885	1.4662
4	9.244	8.184	4	3.5413	1.7308	4	4.5181	1.9550
5	11.555	10.230	5	4.4266	2.1635	5	5.6476	2.4437
6	13.866	12.2276	6	5.3120	2.5962	6	6.7771	2.9325
7	16.177	14.322	7	6.1973	3.0289	7	7.9066	3.4212
8	18.488	16.368	8	7.0826	3.4616	8	9.0361	3.9100
9	20.800	18.414	9	7.9680	3.8942	9	10.165	4.3987
10	23.111	20.462	10	8.8533	4.3273	10	11.295	4.8875
11	25.422	22.508	11	9.7386	4.7600	11	12.424	5.3762
12	27.733	24.554	12	10.624	5.1927	12	13.555	5.8650
13	30.044	26.600	13	11.509	5.6255	13	14.683	6.3537
14	32.355	28.646	14	12.394	6.0582	14	15.813	6.8425
15	34.666	30.692	15	13.280	6.4909	15	16.942	7.3312
16	36.977	32.738	16	14.165	6.9236	16	18.072	7.8200
17	39.288	34.784	17	15.050	7.3563	17	19.201	8.3087
18	41.599	36.830	18	15.936	7.7890	18	20.331	8.7975
19	43.910	38.876	19	16.821	8.2217	19	21.460	9.2862
20	46.221	40.922	20	17.706	8.6544	20	22.490	9.7750
21	48.532	42.968	21	18.591	9.0871	21	23.719	10.264
22	50.843	45.014	22	19.477	9.5198	22	24.849	10.752
23	53.154	47.060	23	20.362	9.9525	23	25.978	11.241
24	55.465	49.106	24	21.247	10.385	24	27.108	11.7300
25	57.776	51.152	25	22.133	10.818	25	28.237	12.219
26	60.087	53.198	26	23.018	11.251	26	29.367	12.707
27	62.398	55.244	27	23.903	11.683	27	30.496	13.196
28	64.709	57.290	28	24.789	12.116	28	31.626	13.685
29	67.020	59.336	29	25.674	12.549	29	32.755	14.174
30	69.331	61.386	30	26.560	12.981	30	33.885	14.662

PRESSURE OF WATER.

The pressure of water in lbs. per square inch for every foot in height to 300 feet; and then by intervals to 1000 feet head.

Feet Head	Press. Sq. In.	Feet Head	Press. Sq. In.	Feet Head	Press Sq. In.	Feet Head	Press. Sq. In.	Feet Head	Press. Sq. In.
1	0.43	65	28.15	129	55.88	193	83.60	257	111.32
2	0.86	66	28.58	130	56.31	194	84.03	258	111.76
3	1.30	67	29.02	131	56.74	195	84.47	259	112.19
4	1.73	68	29.45	132	57.18	196	84.90	260	112.62
5	2.16	69	29.88	133	57.61	197	85.33	261	113.06
6	2.59	70	30.32	134	58.04	198	85.76	262	113.49
7	3.03	71	30.75	135	58.48	199	86.20	263	113.92
8	3.46	72	31.18	136	58.91	200	86.63	264	114.36
9	3.89	73	31.62	137	59.34	201	87.07	265	114.79
10	4.33	74	32.05	138	59.77	202	87.50	266	115.22
11	4.76	75	32.48	139	60.21	203	87.93	267	115.66
12	5.20	76	32.92	140	60.64	204	88.36	268	116.09
13	5.63	77	33.35	141	61.07	205	88.80	269	116.52
14	6.06	78	33.78	142	61.51	206	89.23	270	116.96
15	6.49	79	34.21	143	61.94	207	89.66	271	117.39
16	6.93	80	34.65	144	62.37	208	90.10	272	117.82
17	7.36	81	35.08	145	62.81	209	90.53	273	118.26
18	7.79	82	35.52	146	63.24	210	90.96	274	118.69
19	8.22	83	35.95	147	63.67	211	91.39	275	119.12
20	8.66	84	36.39	148	64.10	212	91.83	276	119.56
21	9.09	85	36.82	149	64.54	213	92.26	277	119.99
22	9.53	86	37.25	150	64.97	214	92.69	278	120.42
23	9.96	87	37.68	151	65.40	215	93.13	279	120.85
24	10.39	88	38.12	152	65.84	216	93.56	280	121.29
25	10.82	89	38.55	153	66.27	217	93.99	281	121.72
26	11.26	90	38.98	154	66.70	218	94.43	282	122.15
27	11.69	91	39.42	155	67.14	219	94.86	283	122.59
28	12.12	92	39.85	156	67.57	220	95.30	284	123.02
29	12.55	93	40.28	157	68.00	221	95.73	285	123.45
30	12.99	94	40.72	158	68.43	222	96.16	286	123.89
31	13.42	95	41.15	159	68.87	223	96.60	287	124.32
32	13.86	96	41.58	160	69.31	224	97.03	288	124.75
33	14.29	97	42.01	161	69.74	225	97.46	289	125.18
34	14.72	98	42.45	162	70.17	226	97.90	290	125.62
35	15.16	99	42.88	163	70.61	227	98.33	291	126.05
36	15.59	100	43.31	164	71.04	228	98.76	292	126.48
37	16.02	101	43.75	165	71.47	229	99.20	293	126.92
38	16.45	102	44.18	166	71.91	230	99.63	294	127.35
39	16.89	103	44.61	167	72.34	231	100.06	295	127.78

PRESSURE OF WATER—Cont.

Feet Head	Press. Sq. In.	Feet Head	Press. Sq. In.	Feet Head	Press. Sq. In.	Feet Head	Press. Sq. In.	Feet Head	Press. Sq. In.
40	17.32	104	45.05	168	72.77	232	100.49	296	128.22
41	17.75	105	45.48	169	73.20	233	100.93	297	128.65
42	18.19	106	45.91	170	73.64	234	101.36	298	129.08
43	18.62	107	46.34	171	74.07	235	101.79	299	129.51
44	19.05	108	46.78	172	74.50	236	102.23	300	129.95
45	19.49	109	47.21	173	74.94	237	102.66	310	134.28
46	19.92	110	47.64	174	75.37	238	103.09	320	138.62
47	20.35	111	48.08	175	75.80	239	103.53	330	142.95
48	20.79	112	48.51	176	76.23	240	103.96	340	147.28
49	21.22	113	48.94	177	76.67	241	104.39	350	151.61
50	21.65	114	49.38	178	77.10	242	104.83	360	155.94
51	22.09	115	49.81	179	77.53	243	105.26	370	160.27
52	22.52	116	50.24	180	77.97	244	105.69	380	164.61
53	22.95	117	50.68	181	78.40	245	106.13	390	168.94
54	23.39	118	51.11	182	78.84	246	106.56	400	173.27
55	23.82	119	51.54	183	79.27	247	106.99	500	216.58
56	24.26	120	51.98	184	79.70	248	107.43	600	259.90
57	24.69	121	52.41	185	80.14	249	107.86	700	303.22
58	25.12	122	52.84	186	80.57	250	108.29	800	346.54
59	25.55	123	53.28	187	81.00	251	108.73	900	389.86
60	25.99	124	53.71	188	81.43	252	109.16	1000	433.18
61	26.42	125	54.15	189	81.87	253	109.59		
62	26.85	126	54.57	190	82.30	254	110.03		
63	27.29	127	55.01	191	82.73	255	110.46		
64	27.72	128	55.44	192	83.17	256	110.89		

NUMBER OF U. S. GALLONS IN RECTANGULAR TANKS.

For One Foot in Depth.

Width of Tank	LENGTH OF TANK.															
	Ft. 2	Ft. In. 2 6	Ft. 3	Ft. In. 3 6	Ft. 4	Ft. In. 4 6	Ft. 5	Ft. In. 5 6	Ft. 6	Ft. In. 6 6	Ft. 7	Ft. In. 7 6	Ft. 8	Ft. In. 8 6	Ft. 9	Ft. In. 9 6
2 Ft.	29.92	37.40	44.88	52.36	59.84	67.32	74.81	82.29	89.77	97.25	104.73	112.21	119.69	127.17	134.65	142.13
2 6 In.	......	46.75	56.10	65 45	74.80	84.16	93.51	102.86	112.21	121.56	130.91	140.26	149.61	158.96	168.31	177.66
3	......	......	67.32	78.54	89.77	100.99	112.21	123.43	134.65	145.87	157.09	168.31	179.53	190.75	202.97	213.19
3 6 In.	......	......	......	91.64	104.73	117.82	130.91	144.00	157.09	170.18	183 27	196.36	209.45	222.54	235.63	248.73
4	......	......	......	......	119.69	134.65	149 61	164.57	179.53	194.49	209.45	224.41	239.37	254.34	269.30	284.26
4 6 In.	......	......	......	......	......	151.48	168 31	185.14	201.97	218.80	235.63	252.47	269.30	286.13	302.96	319.79
5	......	......	......	......	......	......	187.01	205.71	224.41	243.11	261.82	280.52	299.22	317.92	336.62	355.32
5 6 In.	......	......	......	......	......	......	......	226.28	246.86	267.43	288.00	308.57	329.14	349.71	370.28	390.85
6	......	......	......	......	......	......	......	......	269.30	291.74	314.18	336.62	359.06	381.50	403.94	426.39
6 6 In.	......	......	......	......	......	......	......	......	......	316.05	340.36	364.67	388.98	413.30	437.60	461.92
7	......	......	......	......	......	......	......	......	......	......	366.54	392.72	418.91	445.09	471.27	497.45
7 6 In.	......	......	......	......	......	......	......	......	......	......	......	420.78	448.83	476.88	504.93	532.98
8	......	......	......	......	......	......	......	......	......	......	......	......	478.75	508.67	538.59	568.51
8 6 In.	......	......	......	......	......	......	......	......	......	......	......	......	......	540.46	572.25	604.05
9	......	......	......	......	......	......	......	......	......	......	......	......	......	......	605.92	639.58
9 6 In.	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	675 11

CAPACITY OF CYLINDRICAL TANKS AND CISTERNS.

(In U. S. Gallons of 231 cubic inches).

Inside Diam. Ft. In.	Water Depth 1 Ft.	Water Depth 4 Ft.	Water Depth 5 Ft.	Water Depth 6 Ft.	Water Depth 7 Ft.	Water Depth 8 Ft.	Water Depth 9 Ft	Water Depth 12 Ft.	Water Depth 15 Ft.
4.....	94.0	376	470	564	658	752	846	1128	1410
"....6	119.0	476	595	714	833	952	1071	1428	1785
5.....	146.9	588	734	881	1028	1175	1322	1763	2203
"....6	177.7	711	889	1066	1244	1422	1600	2133	2666
6.....	211.5	846	1058	1269	1481	1692	1904	2538	3173
"....3	229.5	918	1148	1377	1607	1836	2066	2754	3443
"....6	248.2	993	1241	1489	1738	1986	2234	2979	3724
"....9	267.7	1071	1338	1606	1874	2142	2409	3212	4015
7.....	287.9	1152	1439	1727	2015	2303	2591	3455	4318
"....3	308.8	1235	1544	1853	2162	2471	2779	3706	4632
"....6	330.5	1322	1652	1983	2313	2544	2974	3966	4957
"....9	352.9	1412	1764	2117	2470	2823	3176	4235	5293
8.....	376.0	1504	1880	2256	2632	3008	3384	4512	5640
"....3	399.9	1600	1999	2399	2799	3199	3599	4799	5998
"....6	424.5	1698	2122	2547	2971	3396	3820	5094	6367
"....9	449.8	1799	2249	2699	3149	3599	4148	5398	6747
9.....	475.9	1904	2380	2855	3331	3807	4283	5711	7138
"....3	502.7	2011	2514	3016	3519	4022	4524	6032	7540
"....6	530.2	2121	2651	3181	3712	4242	4772	6363	7954
"....9	558.5	2234	2793	3351	3910	4468	5027	6702	8378
10.....	587.5	2350	2938	3525	4113	4700	5288	7050	8813
"....3	617.3	2469	3086	3704	4321	4938	5555	7407	9259
"....6	647.7	2591	3239	3886	4534	5182	5830	7773	9716
"....9	679.0	2716	3395	4074	4753	5432	6111	8147	10184
11.....	710.9	2844	3555	4265	4976	5687	6398	8531	10664
"....3	743.6	2974	3718	4462	5205	5949	6692	8923	11154
"....6	777.0	3108	3885	4662	5439	6216	6993	9324	11655
"....9	811.1	3245	4056	4867	5678	6489	7300	9734	12167
12.....	846.0	3384	4230	5076	5922	6768	7614	10152	12691
"....6	918.0	3672	4590	5508	6426	7344	8262	11016	13770
13.....	992.9	3972	4965	5957	6950	7943	8936	11915	14894
"....6	1070.8	4283	5354	6425	7495	8566	9637	12849	16061
14.....	1151.5	4606	5758	6909	8061	9212	10364	13819	17273
"....6	1235.3	4941	6176	7412	8647	9882	11117	14823	18529
15.....	1321.9	5288	6610	7932	9253	10575	11897	15863	19829
"....6	1411.5	5646	7058	8469	9881	11292	12704	16938	21173

CAPACITY OF CYLINDRICAL TANKS AND CISTERNS—Cont.

(In U. S. Gallons of 231 cubic inches).

Inside Diam. Ft. In.	Water Depth 1 Ft.	Water Depth 4 Ft.	Water Depth 5 Ft.	Water Depth 6 Ft.	Water Depth 7 Ft.	Water Depth 8 Ft.	Water Depth 9 Ft.	Water Depth 12 Ft.	Water Depth 15 Ft.
16.....	1504.1	6016	7520	9024	10528	12032	13537	18049	22561
17.....	1697.9	6792	8490	10188	11886	13583	15281	20375	25469
18.....	1903.6	7614	9518	11421	13325	15228	17132	22843	28553
19.....	2120.9	8484	10605	12726	14847	16968	19089	25451	31814
20.....	2350.1	9400	11750	14100	16451	18801	21151	28201	35251
21.....	2590.8	10363	12954	15545	18136	20726	23317	31090	38862
22.....	2843.6	11374	14218	17062	19905	22749	25592	34123	42654
23.....	3107.9	12432	15540	18647	21755	24863	27971	37295	46619
24.....	3384.1	13536	16921	20305	23689	27073	30457	40609	50762
25.....	3671.7	14687	18359	22030	25702	29374	33045	44060	55076
26.....	3971.6	15887	19858	23830	27801	31773	35745	47660	59575
27.....	4282.7	17131	21414	25696	29979	34262	38544	51392	64241
28.....	4606.2	18425	23031	27637	32243	36849	41455	55274	69092
29.....	4940.7	19763	24704	29644	34585	39526	44466	59288	74111
30.....	5287.7	21151	26438	31726	37014	42301	47589	63452	79315
31.....	5645.7	22583	28229	33874	39520	45166	50811	67748	84686
32.....	6016.2	24065	30081	36097	42113	48130	54146	72194	90243
33.....	6397.6	25590	31988	38386	44783	51181	57578	76771	95964
34.....	6791.2	27165	33956	40747	47538	54330	61121	81494	101868
35.....	7197.1	28788	35986	43183	50380	57577	64774	86365	107957
36.....	7614.4	30458	38072	45686	53301	60915	68530	91372	114216
37.....	8043.1	32172	40216	48259	56302	64345	72388	96517	120647
38.....	8483.7	33935	42419	50902	59386	67870	76353	101804	127256
39.....	8936.2	35745	44681	53617	62553	71490	80426	107234	134043
40.....	9400.3	37601	47002	56402	65802	75202	84603	112804	141005
42.....	10362.7	41451	51814	62176	72539	82902	93264	124357	155441
45.....	11897.3	47589	59486	71384	83281	95178	107075	142767	178459
47.....	12977.1	51908	64886	77863	90840	103817	116794	155725	194657
50.....	14688.0	58752	73440	88128	102816	117504	132192	176256	220319
60.....	21150.7	84603	105753	126904	148055	169205	190356	253808	317260
70.....	28788.4	115154	143942	172730	201519	230307	259096	345461	431826
80.....	37600.8	150403	188004	225605	263206	300806	338407	451210	564012
90.....	47588.8	190355	237944	285533	333122	380710	428299	571066	713832
100.....	58752.0	235008	293760	352512	411264	470016	528768	705024	881280

TABLE OF U. S. GALLONS PER MINUTE AND THEIR EQUIVALENTS.

Gallons per Minute.	Gallons per 24 Hours.	Cubic Feet Per Sec.	Gallons per Minute.	Gallons per 24 Hours.	Cubic Feet Per Sec.
1	1440	0.002	350	504000	0.780
10	14400	.022	360	518400	.802
20	28800	.044	370	532800	.825
30	43200	.067	380	547200	.847
40	57600	.089	390	561600	.869
50	72000	.121	400	576000	.892
60	86400	.134	410	590400	.914
70	100800	.156	420	604800	.936
80	115200	.178	430	619200	.958
90	129600	.200	440	633600	.981
100	144000	.223	450	648000	1.003
110	158400	.245	460	662400	1.025
120	172800	.268	470	676800	1.048
130	187200	.290	480	691200	1.069
140	201600	.312	490	705600	1.091
150	216000	.335	500	720000	1.112
160	230400	.357	510	734400	1.136
170	244800	.380	520	748800	1.159
180	259200	.401	530	763200	1.181
190	273600	.424	540	777600	1.202
200	288000	.446	550	792000	1.222
210	302400	.468	560	806400	1.243
220	316800	.490	570	820800	1.269
230	331200	.513	580	835200	1.291
240	345600	.535	590	849600	1.312
250	360000	.557	600	864000	1.337
260	374400	.579	610	878400	1.359
270	388800	.601	620	892800	1.381
280	403200	.624	630	907200	1.402
290	417600	.647	640	921600	1.426
300	432000	.669	650	936000	1.449
310	446400	.691	660	950400	1.470
320	460800	.713	670	964800	1.492
330	475200	.736	680	979200	1.515
340	489600	.758	690	993600	1.538

TABLE OF U. S. GALLONS PER MINUTE AND THEIR EQUIVALENTS—Cont.

Gallons per Minute.	Gallons per 24 Hours.	Cubic Feet Per Sec.	Gallons per Minute.	Gallons per 24 Hours.	Cubic Feet Per Sec.
700	1008000	1.559	1250	1800000	2.785
710	1022400	1.581	1300	1872000	2.893
720	1036800	1.602	1350	1944000	3.009
730	1051200	1.627	1400	2016000	3.119
740	1065600	1.649	1450	2088000	3.230
750	1080000	1.671	1500	2160000	3.341
760	1094400	1.692	1550	2232000	3.453
770	1108800	1.715	1600	2304000	3.562
780	1123200	1.738	1650	2376000	3.676
790	1137600	1.760	1700	2448000	3.785
800	1152000	1.782	1750	2520000	3.899
810	1166400	1.802	1800	2592000	4.010
820	1180800	1.827	1850	2664000	4.121
830	1195200	1.849	1900	2736000	4.233
840	1209600	1.871	1950	2808000	4.344
850	1224000	1.892	2000	2880000	4.456
860	1238400	1.918	2050	2952000	4.567
870	1252800	1.936	2100	3024000	4.683
880	1267200	1.960	2150	3096000	4.790
890	1281600	1.982	2200	3168000	4.901
900	1296000	2.005	2250	3240000	5.013
910	1310400	2.027	2300	3312000	5.125
920	1324800	2.048	2350	3384000	5.235
930	1339200	2.073	2400	3456000	5.347
940	1353600	2.093	2450	3528000	5.458
950	1368000	2.114	2500	3600000	5.570
960	1382400	2.138	2550	3672000	5.681
970	1396800	2.161	2600	3744000	5.792
980	1411200	2.181	2650	3816000	5.904
990	1425600	2.202	2700	3888000	6.015
1000	1440000	2.228	2750	3960000	6.127
1050	1512000	2.339	2800	4032000	6.245
1100	1584000	2.450	2850	4104000	6.349
1150	1656000	2.562	2900	4176000	6.464
1200	1728000	2.672	2950	4248000	6.573
....	....	.....	3000	4320000	6.684

TABLE FOR CALCULATING THE HORSE-POWER OF WATER.

The following table gives the horse-power that may be developed under normal conditions with one cubic foot of water per minute under heads from one up to eleven hundred feet:

Heads in Feet.	Horse-Power.	Heads in Feet.	Horse-Power.
1	.0016098	320	.515136
20	.032196	330	.531234
30	.048294	340	.547332
40	.064392	350	.563430
50	.080490	360	.579528
60	.096588	370	.595626
70	.112686	380	.611724
80	.128784	390	.627822
90	.144892	400	.643920
100	.160980	410	.660018
110	.177078	420	.676116
120	.193176	430	.692214
130	.209274	440	.708312
140	.225372	450	.724410
150	.241470	460	.740508
160	.257568	470	.756606
170	.273666	480	.772704
180	.289764	490	.788802
190	.305862	500	.804900
200	.321960	520	.837096
210	.338058	540	.869292
220	.354156	560	.901488
230	.370254	580	.933684
240	.386352	600	.965880
250	.402450	650	1.046370
260	.418548	700	1.126860
270	.434646	750	1.207350
280	.450744	800	1.287840
290	.466842	900	1.448820
300	.482940	1,000	1.609800
310	.499038	1,100	1.770780

Contents in cubic feet, U. S. gallons and weight of water per foot length for pipe of various diameters, also area in square feet and inches, and circumference in inches.

Diameter of Pipe in inches.	Area in sq. feet or contents in cubic feet per foot of length.	Contents in U. S. gallons per foot length.	Weight of water in one foot length, in lbs.	Area in sq. in.	Circumference in inches.
1	.0055	.0408	.34	.78	3.14
2	.0218	.1632	1.36	3.14	6.28
3	.0491	.3672	3.06	7.06	9.42
4	.0873	.6528	5.44	12.56	12.56
5	.1364	1.020	8.51	19.63	15.70
6	.1963	1.469	12.25	28.27	18.85
7	.2673	1.999	16.68	38.48	21.99
8	.3491	2.611	21.79	50.26	25.13
9	.4418	3.305	27.57	63.61	28.27
10	.5454	4.08	34.04	78.54	31.41
11	.66	4.937	41.19	95.03	34.55
12	.7854	5.875	49.02	113.10	37.69
13	.9218	6.895	57.54	132.73	40.84
14	1.069	7.997	66.73	153.94	43.98
15	1.227	9.180	76.60	176.71	47.12
16	1.396	10.44	87.16	201.06	50.26
18	1.768	13.22	110.31	254.47	56.54
20	2.182	16.32	136.19	314.16	62.83
22	2.640	19.75	164.79	380.13	69.11
24	3.142	23.50	196.11	452.39	75.39
26	3.687	27.58	230.16	530.93	81.68
28	4.276	31.99	266.93	615.75	87.96
30	4.909	36.72	306.42	706.86	94.24
32	5.585	41.78	348.64	804.25	100.53
34	6.305	47.16	393.59	907.92	106.81
36	7.069	52.88	441.25	1017.9	113.09
38	7.876	58.92	491.64	1134.1	119.38
40	8.727	65.28	544.76	1256.6	125.66
42	9.621	71.97	600.59	1385.4	131.94
44	10.559	78.99	659.16	1520.5	138.23
46	11.541	86.33	720.44	1661.9	144.51
48	12.566	94.00	784.45	1809.6	150.79
50	13.635	102.00	851.18	1963.5	157.08
52	14.748	110.32	920.64	2123.7	163.36
54	15.90	118.97	992.82	2290.2	169.64
60	19.63	146.88	1225.71	2827.4	188.49
66	23.76	177.72	1483.11	3421.2	207.34
72	28.27	211.51	1765.02	4071.5	226.19

DECIMAL EQUIVALENTS OF AN INCH.

By 64ths: from 1/64 to 1 inch.

Fraction	Decimal	Fraction	Decimal	Fraction	Decimal	Fraction	Decimal
1/64	.015625	17/64	.265625	33/64	.515625	49/64	.765625
1/32	.031250	9/32	.281250	17/32	.531250	35/64	.781250
3/64	.046875	19/64	.296875	35/64	.546875	51/64	.796875
1/16	.062500	5/16	.312500	9/16	.562500	13/16	.812500
5/64	.078125	21/64	.328125	37/64	.578125	53/64	.828125
3/32	.093750	11/32	.343750	19/32	.593750	27/32	.843750
7/64	.109375	23/64	.359375	39/64	.609375	55/64	.859375
1/8	.125000	3/8	.375000	5/8	.625000	7/8	.875000
9/64	.140625	25/64	.390625	41/64	.640625	57/64	.890625
5/32	.156250	13/32	.406250	21/32	.656250	29/32	.906250
11/64	.171875	27/64	.421875	43/64	.671875	59/64	.921875
3/16	.187500	7/16	.437500	11/16	.687500	15/16	.937500
13/64	.203125	29/64	.453125	45/64	.703125	61/64	.953125
7/32	.218750	15/32	.468750	23/32	.718750	31/32	.968750
15/64	.234375	31/64	.484375	47/64	.734375	63/64	.984375
1/4	.250000	1/2	.500000	3/4	.750000	1	1.000000

TABLE GIVING AREAS OF CIRCLES.

From 1/32 to 2 inches diameter.

Diameter.	Area.	Circum.	Diameter.	Area.	Circum.
1/32	·000767	·09817	1 1/32	·83525	3·2398
1/16	·003068	·19635	1 1/16	·88665	3·3379
3/32	·006903	·29452	1 3/32	·93956	3·4361
1/8	·012272	·39270	1 1/8	·99402	3·5343
5/32	·019175	·49087	1 5/32	1·0500	3·6325
3/16	·027612	·58905	1 3/16	1·1075	3·7306
7/32	·037583	·68722	1 7/32	1·1666	3·8288
1/4	·049087	·78540	1 1/4	1·2272	3·9270
9/32	·062126	·88357	1 9/32	1·2893	4·0252
5/16	·076699	·98175	1 5/16	1·3530	4·1233
11/32	·092806	1·0799	1 11/32	1·4182	4·2215
3/8	·11045	1·1781	1 3/8	1·4849	4·3197
13/32	·12962	1·2763	1 13/32	1·5531	4·4179
7/16	·15033	1·3744	1 7/16	1·6229	4·5160
15/32	·17257	1·4726	1 15/32	1·6943	4·6142
1/2	·19635	1·5708	1 1/2	1·7671	4·7124
17/32	·22166	1·6690	1 17/32	1·8415	4·8106
9/16	·24850	1·7671	1 9/16	1·9175	4·9087
19/32	·27688	1·8653	1 19/32	1·9949	5·0069
5/8	·30680	1·9635	1 5/8	2·0739	5·1051
21/32	·33824	2·0617	1 21/32	2·1545	5·2033
11/16	·37122	2·1598	1 11/16	2·2365	5·3014
23/32	·40574	2·2580	1 23/32	2·3201	5·3996
3/4	·44179	2·3562	1 3/4	2·4053	5·4978
25/32	·47937	2·4544	1 25/32	2·4919	5·5959
13/16	·51849	2·5525	1 13/16	2·5801	5·6941
27/32	·55914	2·6507	1 27/32	2·6699	5·7923
7/8	·60132	2·7489	1 7/8	2·7612	5·8905
29/32	·64504	2·8471	1 29/32	2·8540	5·9886
15/16	·69029	2·9452	1 15/16	2·9483	6·0868
31/32	·73708	3·0434	1 31/32	3·0442	6·1850
1	·78540	3·1416	2	3·1416	6·2832

Table of the Areas of Circles.

Diameters.	Areas.								Diameters.
	·0	·⅛	·¼	·⅜	·½	·⅝	·¾	·⅞	
0	·0	·01227	·0491	·1104	·1963	·3068	·4418	·6013	0
1	·78540	·99402	1·2272	1·4849	1·7671	2·0739	2·4053	2·7612	1
2	3·1416	3·5466	3·9761	4·4301	4·9087	5·4119	5·9396	6·4918	2
3	7·0686	7·6699	8·2958	8·9462	9·6211	10·3206	11·0447	11·7933	3
4	12·5664	13·3641	14·1863	15·0330	15·9048	16·8002	17·7206	18·6655	4
5	19·6350	20·6290	21·6476	22·6907	23·7583	24·8505	25·9673	27·1086	5
6	28·2744	29·4648	30·6797	31·9191	33·1831	34·4717	35·7848	37·1224	6
7	38·4846	39·8713	41·2826	42·7184	44·1787	45·6636	47·1731	48·7071	7
8	50·2656	51·8487	53·4563	55·0884	56·7451	58·4264	60·1322	61·8625	8
9	63·6174	65·3968	67·2008	69·0293	70·8823	72·7599	74·6621	76·5888	9
10	78·5400	80·5158	82·5161	84·5409	86·5903	88·6643	90·7628	92·8858	10
11	95·0334	97·2055	99·5022	101·6234	103·8691	106·1394	108·4343	110·7537	11
12	113·098	115·466	117·859	120·277	122·719	125·185	127·677	130·192	12
13	132·733	135·297	137·887	140·501	143·139	145·802	148·490	151·202	13
14	153·938	156·700	159·485	162·296	165·130	167·990	170·874	173·782	14
15	176·715	179·673	182·655	185·661	188·692	191·748	194·828	197·933	15
16	201·062	204·216	207·395	210·598	213·825	217·077	220·354	223·655	16
17	226·981	230·331	233·706	237·105	240·529	243·977	247·450	250·948	17
18	254·470	258·016	261·587	265·183	268·803	272·448	276·117	279·811	18
19	283·529	287·272	291·040	294·832	298·648	302·489	306·355	310·245	19
20	314·160	318·099	322·063	326·051	330·064	334·102	338·164	342·250	20
21	346·361	350·497	354·657	358·842	363·051	367·285	371·543	375·826	21
22	380·134	384·466	388·822	393·203	397·609	402·038	406·494	410·973	22

Table of the Areas of Circles—Cont.

Diameters.	Areas.								Diameters.
	·0	·⅛	·¼	·⅜	·½	·⅝	·¾	·⅞	
23	415·477	420·004	424·558	429·135	433·737	438·364	443·015	447·690	23
24	452·390	457·115	461·864	466·638	471·436	476·259	481·107	485·979	24
25	490·875	495·796	500·742	505·712	510·706	515·726	520·769	525·838	25
26	530·930	536·048	541·190	546·356	551·547	556·763	562·003	567·267	26
27	572·557	577·870	583·209	588·571	593·959	599·371	604·807	610·268	27
28	615·754	621·264	626·798	632·357	637·941	643·549	649·182	654·840	28
29	660·521	666·228	671·959	677·714	683·494	689·299	695·128	700·982	29
30	706·860	712·763	718·690	724·642	730·618	736·619	742·645	748·695	30
31	754·769	760·869	766·992	773·140	779·313	785·510	791·732	797·979	31
32	804·250	810·545	816·865	823·210	829·579	835·972	842·391	848·833	32
33	855·301	861·792	868·309	874·850	881·415	888·005	894·620	901·259	33
34	907·922	914·611	921·323	928·061	934·822	941·609	948·420	955·255	34
35	962·115	969·000	975·909	982·842	989·800	996·783	1003·790	1010·822	35
36	1017·878	1024·960	1032·065	1039·195	1046·349	1053·528	1060·732	1067·960	36
37	1075·213	1082·490	1089·792	1097·118	1104·469	1111·844	1119·244	1126·669	37
38	1134·118	1141·591	1149·089	1156·612	1164·159	1171·731	1179·327	1186·948	38
39	1194·593	1202·263	1209·958	1217·677	1225·420	1233·188	1240·981	1248·798	39
40	1256·64	1264·51	1272·40	1280·31	1288·25	1296·22	1304·21	1312·22	40
41	1320·26	1328·32	1336·41	1344·52	1352·66	1360·82	1369·00	1377·21	41
42	1385·45	1393·70	1401·99	1410·30	1418·63	1426·99	1435·37	1443·77	42
43	1452·20	1460·66	1469·14	1477·64	1486·17	1494·73	1503·30	1511·91	43
44	1520·53	1529·19	1537·86	1546·56	1555·29	1564·04	1572·81	1581·61	44

Table of the Areas of Circles—Cont.

Diameters.	Areas.								Diameters.
	·0	·⅛	·¼	·⅜	·½	·⅝	·¾	·⅞	
45	1590·43	1599·28	1608·16	1617·05	1625·97	1634·92	1643·89	1652·89	45
46	1661·91	1670·95	1680·02	1689·11	1698·23	1707·37	1716·54	1725·73	46
47	1734·95	1744·19	1753·45	1762·74	1772·06	1781·40	1790·76	1800·15	47
48	1809·56	1819·00	1828·46	1837·95	1847·46	1856·99	1866·55	1876·14	48
49	1885·75	1895·38	1905·04	1914·72	1924·43	1934·16	1943·91	1953·69	49
50	1963·50	1973·33	1983·18	1993·06	2002·97	2012·89	2022·85	2032·82	50
51	2042·83	2052·85	2062·90	2072·98	2083·08	2093·20	2103·35	2113·52	51
52	2123·72	2133·94	2144·19	2154·46	2164 76	2175·08	2185·42	2195·79	52
53	2206·19	2216·61	2227·05	2237·52	2248·01	2258·53	2269·07	2279·64	53
54	2290·23	2300·84	2311·48	2322·15	2332·83	2343·55	2354·29	2365·05	54
55	2375·83	2386·65	2397·48	2408·34	2419·23	2430·14	2441·07	2452·03	55
56	2463·01	2474·02	2485·05	2496·11	2507·19	2518·30	2529·43	2540·58	56
57	2551·76	2562·97	2574·20	2585·45	2596·73	2608·03	2619·36	2630·71	57
58	2642·09	2653·49	2664·91	2676·36	2687·84	2699·33	2710·86	2722·41	58
59	2733·98	2745·57	2757·20	2768·84	2780·51	2792·21	2803·93	2815·67	59
60	2827·44	2839·23	2851·05	2862·89	2874·76	2886·65	2898·57	2910·51	60
61	2922·47	2934·46	2946·48	2958·52	2970·58	2982·67	2994·78	3006·92	61
62	3019·08	3031·26	3043·47	3055·71	3067·97	3080·25	3092·56	3104·89	62
63	3117·25	3129·64	3142·04	3154·47	3166·93	3179·41	3191·91	3204·44	63
64	3217·00	3229·58	3242·18	3254·81	3267·46	3280·14	3292·84	3305·56	64
65	3318·31	3331·09	3343·89	3356·71	3369·56	3382·44	3395·33	3408·26	65
66	3421·20	3434·17	3447·17	3460·19	3473·24	3486 30	3499·40	3512·52	66

Table of the Areas of Circles—Cont.

Diameters.	Areas.								Diameters.
	·0	·⅛	·¼	·⅜	·½	·⅝	·¾	·⅞	
67	3525·66	3538·83	3552·02	3565·24	3578·48	3591·74	3605·04	3618·35	67
68	3631·69	3645·05	3658·44	3671·86	3685·29	3698·76	3712·24	3725·75	68
69	3739·29	3752·85	3766·43	3780·04	3793·68	3807·34	3821·02	3834·73	69
70	3848·46	3862·22	3876·00	3889·80	3903·63	3917·49	3931·37	3945·27	70
71	3959·20	3973·15	3987·13	4001·13	4015·16	4029·21	4043·29	4057·39	71
72	4071·51	4085·66	4099·84	4114·04	4128·26	4142·51	4156·78	4171·08	72
73	4185·40	4199·74	4214·11	4228·51	4242·93	4257·37	4271·84	4286·83	73
74	4300·85	4315·39	4329·96	4344·55	4359·17	4373·81	4388·47	4403·16	74
75	4417 87	4432·61	4447·38	4462·16	4476·98	4491·81	4506·67	4521·56	75
76	4536·47	4551·41	4566·36	4581·35	4596·36	4611·39	4626·45	4641·53	76
77	4656·64	4671 77	4686·92	4702·10	4717·31	4732·54	4747·79	4763·07	77
78	4778·37	4793·70	4809 05	4824·43	4839·83	4855·26	4870·71	4886·18	78
79	4901·68	4917·21	4932·75	4948·33	4963·92	4979·55	4995·19	5010·86	79
80	5026·56	5042·28	5058·03	5073·79	5089·59	5105·41	5121·25	5137·12	80
81	5153·01	5168·93	5184·87	5200·83	5216·82	5232·84	5248·88	5264·94	81
82	5281·03	5297·14	5313·28	5329·44	5345·63	5361·84	5378·08	5394·34	82
83	5410·62	5426·93	5443·26	5459·62	5476·01	5492·41	5508·84	5525·30	83
84	5541·78	5558·29	5574·82	5591·37	5607·95	5624·56	5641·18	5657·84	84
85	5674·51	5691 22	5707·94	5724·69	5741·47	5758·27	5775·10	5791·94	85
86	5808·82	5825·72	5842·64	5859·59	5876·56	5893·55	5910·58	5927·62	86
87	5944·69	5961·79	5978·91	5996·05	6013·22	6030·41	6047·63	6064·87	87
88	6082·14	6099·43	6116·74	6134·08	6151·45	6168·84	6186·25	6203·69	88

Table of the Areas of Circles—Cont.

Diameters.	Areas.								Diameters
	·0	·⅛	·¼	·⅜	·½	·⅝	·¾	·⅞	
89	6221·15	6238·64	6256·15	6273·69	6291·25	6308·84	6326·45	6344·08	89
90	6361·74	6379·42	6397·13	6414·86	6432·62	6450·40	6468·21	6486·04	90
91	6503·90	6521·78	6539·68	6557·61	6575·56	6593·54	6611·55	6629·57	91
92	6647·63	6665·70	6683·80	6701·93	6720·08	6738·25	6756·45	6774·68	92
93	6792·92	6811·20	6829·49	6847·82	6866·16	6884·53	6902·93	6921·35	93
94	6939·79	6958·26	6976·76	6995·28	7013·82	7032·39	7050·98	7069·59	94
95	7088·24	7106·90	7125·59	7144·31	7163·04	7181·81	7200·60	7219·41	95
96	7238·25	7257·11	7275·99	7294·91	7313·84	7332·80	7351·79	7370·79	96
97	7389·83	7408·89	7427·97	7447·08	7466·21	7485·37	7504·55	7523·75	97
98	7542·98	7562·24	7581·52	7600·82	7620·15	7639·50	7658·88	7678·28	98
99	7697·71	7717·16	7736·63	7756·13	7775·66	7795·21	7814·78	7834·38	99
100	7854·00	7873·64	7893·31	7913·00	7932·74	7952·47	7972·25	7992·03	100
101	8011·86	8031·69	8051·58	8071·46	8091·39	8111·32	8131·30	8151·28	101
102	8171·30	8191·33	8211·41	8231·49	8251·61	8271·73	8291·91	8312·09	102
103	8332·31	8352·53	8372·81	8393·08	8413·40	8433·73	8454·09	8474·47	103
104	8494·89	8515·31	8535·78	8556·25	8576·76	8597·28	8617·85	8638·42	104
105	8659·03	...	8700·32	...	8741·70	...	8783·18	...	105
106	8824·75	...	8866·43	...	8908·20	...	8950·07	...	106
107	8992·04	...	9034·11	...	9076·28	...	9118·54	...	107
108	9160·91	...	9203·37	...	9245·93	...	9288·58	...	108
109	9331·34	...	9374·19	...	9417·14	...	9460·19	...	109
110	9503·34	...	9546·59	...	9589·93	...	9633·37	...	110

Table of the Areas of Circles—Cont.

Diameters.	Areas. ·0	·⅛	·¼	·⅜	·½	·⅝	·¾	·⅞	Diameters.
111	9676·91	...	9720·55	...	9764·29	...	9808·12	...	111
112	9852·06	...	9896·09	...	9940·22	...	9984·45	...	112
113	10028·77	...	10073·20	...	10117·72	...	10162·34	...	113
114	10207·06	...	10251·88	...	10296·79	...	10341·80	...	114
115	10386·91	...	10432·12	...	10477·43	...	10522·84	...	115
116	10568·34	...	10613·94	...	10659·65	...	10705·44	...	116
117	10751·34	...	10797·34	...	10843·43	...	10889·62	...	117
118	10935·91	...	10982·30	...	11028·78	...	11075·37	...	118
119	11122·05	...	11168·83	...	11215·71	...	11262·69	...	119
120	11309·76	...	11356·93	...	11404·20	...	11451·57	...	120
121	11499·04	...	11546·61	...	11594·27	...	11642·03	...	121
122	11689·89	...	11737·85	...	11785·91	...	11834·06	...	122
123	11882·32	...	11930·67	...	11979·12	...	12027·66	...	123
124	12076·31	...	12125·05	...	12173·90	...	12222·84	...	124
125	12271·87	...	...	...	12370·25	...	...	...	125
126	12469·01	...	...	...	12568·17	...	...	...	126
127	12667·72	...	...	...	12767·66	...	...	...	127
128	12867·99	...	...	...	12968·72	...	...	...	128
129	13069·84	...	...	...	13171·35	...	...	...	129
130	13273·26	...	...	...	13375·56	...	...	...	130
131	13478·25	...	...	...	13581·33	...	...	...	131
132	13684·81	...	...	...	13788·68	...	...	...	132

Table of the Areas of Circles—Cont.

Diameters.	Areas. ·0	·1/8	·1/4	·3/8	·1/2	·5/8	·3/4	·7/8	Diameters.
133	13892·94	...	...	...	13997·60	...	...	...	133
134	14102·64	...	...	...	14208·08	...	...	...	134
135	14313·91	...	...	...	14420·14	...	...	...	135
136	14526·76	...	...	...	14633·77	...	...	...	136
137	14741 17	...	...	...	14848·97	...	...	...	137
138	14957·16	...	...	...	15065·74	...	...	...	138
139	15174·71	...	...	...	15284·08	...	...	...	139
140	15393·84	...	...	...	15503·99	...	...	...	140
141	15614·54	...	...	...	15725·48	...	...	...	141
142	15836·81	...	...	...	15948·53	...	...	...	142
143	16060·64	...	...	...	16173·15	...	...	...	143
144	16286·05	...	...	...	16399·35	...	...	...	144
145	16513·03	...	...	...	16627·11	...	...	...	145
146	16741·59	...	...	...	16856·45	...	...	...	146
147	16971·71	...	...	...	17087·36	...	...	...	147
148	17203·40	...	...	...	17319·84	...	...	...	148
149	17436·67	...	...	...	17553·89	...	...	...	149
150	17671·50	...	...	...	17789·51	...	...	...	150

Where the diameter contains an odd sixteenth, take one fourth of the area of twice the diameter; *e.g.*, area of $2\frac{1}{16} = \frac{\text{Area of } 4\frac{1}{8}}{4}$, &c. Areas of intermediate sizes may also be obtained by shifting the decimal point; *e.g.*, area, 132 = 13684·81, area of 13·2 = 136·8481; area of 1·32 = 1·368481, &c.

Table of the Circumferences of Circles.

Diameters.	Circumferences. ·0	·⅛	·¼	·⅜	·½	·⅝	·¾	·⅞	Diameters.
0	·0	·3927	·7854	1·1781	1·5708	1·9635	2·3562	2·7489	0
1	3·1416	3·5343	3·9270	4·3197	4·7124	5·1051	5·4978	5·8905	1
2	6·2832	6·6759	7·0686	7·4613	7·8540	8·2467	8·6394	9·0321	2
3	9·4248	9·8175	10·2102	10·6029	10·9956	11·3883	11·7810	12·1737	3
4	12·5664	12·9591	13·3518	13·7445	14·1372	14·5299	14·9226	15·3153	4
5	15·7080	16·1007	16·4934	16·8861	17·2788	17·6715	18·0642	18·4569	5
6	18·8496	19·2423	19·6350	20·0277	20·4204	20·8131	21·2058	21·5985	6
7	21·9912	22·3839	22·7766	23·1693	23·5620	23·9547	24·3474	24·7401	7
8	25·1328	25·5255	25·9182	26·3109	26·7036	27·0963	27·4890	27·8817	8
9	28·2744	28·6671	29·0598	29·4525	29·8452	30·2379	30·6306	31·0233	9
10	31·4160	31·8087	32·2014	32·5941	32·9868	33·3795	33·7722	34·1649	10
11	34·5576	34·9503	35·3430	35·7357	36·1284	36·5211	36·9138	37·3065	11
12	37·6992	38·0919	38·4846	38·8773	39·2700	39·6627	40·0554	40·4481	12
13	40·8408	41·2335	41·6262	42·0189	42·4116	42·8043	43·1970	43·5897	13
14	43·9824	44·3751	44·7678	45·1605	45·5532	45·9459	46·3386	46·7313	14
15	47·1240	47·5167	47·9094	48·3021	48·6948	49·0875	49·4802	49·8729	15
16	50·2656	50·6583	51·0510	51·4437	51·8364	52·2291	52·6218	53·0145	16
17	53·4072	53·7999	54·1926	54·5853	54·9780	55·3707	55·7634	56·1561	17
18	56·5488	56·9415	57·3342	57·7269	58·1196	58·5123	58·9050	59·2977	18
19	59·6904	60·0831	60·4758	60·8685	61·2612	61·6539	62·0466	62·4393	19
20	62·8320	63·2247	63·6174	64·0101	64·4028	64·7955	65·1882	65·5809	20
21	65·9736	66·3663	66·7590	67·1517	67·5444	67·9371	68·3298	68·7225	21
22	69·1152	69·5079	69·9006	70·2933	70·6860	71·0787	71·4714	71·8641	22

Table of the Circumferences of Circles—Cont.

Diameters.	Circumferences. ·0	·1/8	·1/4	·3/8	·1/2	·5/8	·3/4	·7/8	Diameters.
23	72·2568	72·6495	73·0422	73·4349	73·8276	74·2203	74·6130	75·0057	23
24	75·3984	75·7911	76·1838	76·5765	76·9692	77·3619	77·7546	78·1473	24
25	78·5400	78·9327	79·3254	79·7181	80·1108	80·5035	80·8962	81·2889	25
26	81·6816	82·0743	82·4670	82·8597	83·2524	83·6451	84·0378	84·4305	26
27	84·8232	85·2159	85·6086	86·0013	86·3940	86·7867	87·1794	87·5721	27
28	87·9648	88·3575	88·7502	89·1429	89·5356	89·9283	90·3210	90·7137	28
29	91·1064	91·4991	91·8918	92·2845	92·6772	93·0699	93·4626	93·8553	29
30	94·2480	94·6407	95·0334	95·4261	95·8188	96·2115	96·6042	96·9969	30
31	97·3896	97·7823	98·1750	98·5677	98·9604	99·3531	99·7458	100·1385	31
32	100·5312	100·9239	101·3166	101·7093	102·1020	102·4947	102·8874	103·2801	32
33	103·6728	104·0655	104·4582	104·8509	105·2436	105·6363	106·0290	106·4217	33
34	106·814	107·207	107·600	107·992	108·385	108·778	109·171	109·563	34
35	109·956	110·349	110·741	111·134	111·527	111·919	112·312	112·705	35
36	113·098	113·490	113·883	114·276	114·668	115·061	115·454	115·846	36
37	116·239	116·632	117·025	117·417	117·810	118·203	118·595	118·988	37
38	119·381	119·773	120·166	120·559	120·952	121·344	121·737	122·130	38
39	122·522	122·915	123·308	123·700	124·093	124·486	124·879	125·271	39
40	125·664	126·057	126·449	126·842	127·235	127·627	128·020	128·413	40
41	128·806	129·198	129·591	129·984	130·376	130·769	131·162	131·554	41
42	131·947	132·340	132·733	133·125	133·518	133·911	134·303	134·696	42
43	135·089	135·481	135·874	136·267	136·660	137·052	137·445	137·838	43
44	138·230	138·623	139·016	139·408	139·801	140·194	140·587	140·979	44

Table of the Circumferences of Circles—Cont.

Diameters.	Circumferences.								Diameters.
	·0	·⅛	·¼	·⅜	·½	·⅝	·¾	·⅞	
45	141·372	141·765	142·157	142·550	142·943	143·335	143·728	144·121	45
46	144·514	144·906	145·299	145·692	146·084	146·477	146·870	147·262	46
47	147·655	148·048	148·441	148·833	149·226	149·619	150·011	150·404	47
48	150·797	151·189	151·582	151·975	152·368	152·760	153·153	153·546	48
49	153·938	154·331	154·724	155·116	155·509	155·902	156·295	156·687	49
50	157·080	157·473	157·865	158·258	158·651	159·043	159·436	159·829	50
51	160·222	160·614	161·207	161·400	161·792	162·185	162·578	162·970	51
52	163·363	163·756	164·149	164·541	164·934	165·327	165·719	166·112	52
53	166·505	166·897	167·290	167·683	168·076	168·468	168·861	169·254	53
54	169·646	170·039	170·432	170·824	171·217	171·610	172·003	172·395	54
55	172·788	173·181	173·573	173·966	174·359	174·751	175·144	175·537	55
56	175·930	176·322	176·715	177·108	177·500	177·893	178·286	178·678	56
57	179·071	179·464	179·857	180·249	180·642	181·035	181·427	181·820	57
58	182·213	182·605	182·998	183·391	183·784	184·176	184·569	184·962	58
59	185·354	185·747	186·140	186·532	186·925	187·318	187·711	188·103	59
60	188·496	188·889	189·281	189·674	190·067	190·459	190·852	191·245	60
61	191·638	192·030	192·423	192·816	193·208	193·601	193·994	194·396	61
62	194·779	195·172	195·565	195·957	196·350	196·743	197·135	197·528	62
63	197·921	198·313	198·706	199·099	199·492	199·884	200·277	200·670	63
64	201·062	201·455	201·848	202·240	202·633	203·026	203·419	203·811	64
65	204·204	204·597	204·989	205·382	205·775	206·167	206·560	206·953	65
66	207·346	207·738	208·131	208·524	208·916	209·309	209·702	210·094	66

Table of the Circumferences of Circles—Cont.

Diameters.	Circumferences.								Diameters.
	·0	·⅛	·¼	·⅜	·½	·⅝	·¾	·⅞	
67	210·487	210·880	211·273	211·665	212·058	212·451	212·843	213·236	67
68	213·629	214·021	214·414	214·807	215·200	215 592	215·985	216·378	68
69	216·770	217·163	217·556	217·948	218·341	218·734	219·127	219·519	69
70	219·912	220·305	220·697	221·090	221·483	221·875	222·268	222·661	70
71	223·054	223·446	223·839	224·232	224 624	225·017	225·410	225·802	71
72	226·195	226·588	226·981	227·373	227·766	228·158	228·551	228·944	72
73	229·337	229·729	230·122	230·515	230·908	231·300	231·693	232·086	73
74	232·478	232·871	233·264	233·656	234·049	234·442	234·835	235·227	74
75	235·620	236·013	236·405	236·798	237·191	237·583	237·976	238·369	75
76	238·762	239·154	239·547	239·940	240·332	240·725	241·118	241·510	76
77	241·903	242·296	242·689	243·081	243·474	243·867	244·259	244·652	77
78	245·045	245·437	245·830	246·223	246·616	247·008	247·401	247·794	78
79	248·186	248·579	248·972	249·364	249·757	250·150	250·543	250·935	79
80	251·328	251·721	252·113	252·506	252·899	253·291	253·684	254·077	80
81	254·470	254·862	255·255	255·648	256·040	256·433	256·826	257·218	81
82	257·611	258·004	258·397	258·789	259·182	259·575	259·967	260·360	82
83	260·753	261·145	261·538	261·931	262·324	262·716	263·109	263·502	83
84	263·894	264·287	264·680	265·072	265·465	265·858	266·251	266·643	84
85	267·036	267·429	267·821	268·214	268·607	268·999	269·392	269·785	85
86	270·178	270·570	270·963	271·356	271·748	272·141	272·534	272·926	86
87	273·319	273·712	274·105	274·497	274·890	275 283	275·675	276·068	87
88	276·461	276·853	277·246	277·629	278·032	278·424	278·817	279·210	88

Table of the Circumferences of Circles—Cont.

Diameters.	Circumferences.								Diameters.
	·0	·⅛	·¼	·⅜	·½	·⅝	·¾	⅞	
89	279·602	279·995	280·388	280·780	281·173	281·566	281·959	282·351	89
90	282·744	283·137	283·529	283·922	284·315	284·707	285·100	285·493	90
91	285·886	286·278	286·671	287·064	287·456	287·849	288·242	288·634	91
92	289·027	289·420	289·813	290·205	290·598	290·991	291·383	291·776	92
93	292·169	292·562	292·954	293·347	293·740	294·132	294·525	294·918	93
94	295·310	295·703	296·096	296·488	296·881	297·274	297·667	298·059	94
95	298·452	298·845	299·237	299·630	300·023	300·415	300·808	301·201	95
96	301·594	301·986	302·379	302·772	303·164	303·557	303·950	304·342	96
97	304·735	305·128	305·521	305·913	306·306	306·699	307·091	307·484	97
98	307·877	308·270	308·662	309·055	309·448	309·840	310·233	310·626	98
99	311·018	311·411	311·804	312·196	312·589	312·982	313·375	313·767	99
100	314·160	314·553	314·945	315·338	315·731	316·123	316·516	316·909	100
101	317·302	317·694	318·087	318·480	318·872	319·265	319·658	320·050	101
102	320·443	320·836	321·229	321·621	322·014	322·407	322·799	323·192	102
103	323·585	323·977	324·370	324·763	325·156	325·548	325·941	326·334	103
104	326·726	327·119	327·512	327·904	328·297	328·690	329·083	329·475	104
105	329·868	...	330·653	...	331·439	...	332·224	...	105
106	333·010	...	333·795	...	334·580	...	335·366	...	106
107	336·151	...	336·937	...	337·722	...	338·507	...	107
108	339·293	...	340·078	...	340·864	...	341·649	...	108
109	342·434	...	343·220	...	344·005	...	344·791	...	109
110	345·576	...	346·361	...	347·147	...	347·932	...	110

Table of the Circumferences of Circles—Cont.

Diameters.	Circumferences. ·0	·⅛	·¼	·⅜	·½	·⅝	·¾	·⅞	Diameters.
111	348·718	...	349·503	...	350·288	...	351·074	...	111
112	351·859	...	352·645	...	353·430	...	354·215	...	112
113	355·001	...	355·786	...	356·572	...	357·357	...	113
114	358·142	...	358·928	...	359·713	...	360·499	...	114
115	361·284	...	362·069	...	362·855	...	363·640	...	115
116	364·426	...	365·211	...	365·996	...	366·782	...	116
117	367·567	...	368·353	...	369·138	...	369·923	...	117
118	370·709	...	371·494	...	372·280	...	373·065	...	118
119	373·850	...	374·636	...	375·421	...	376·207	...	119
120	376·992	...	377·777	...	378·563	...	379·348	...	120
121	380·134	...	380·919	...	381·704	...	382·490	...	121
122	383·275	...	384·061	...	384·846	...	385 631	...	122
123	386·417	...	387·202	...	387·988	...	388·773	...	123
124	389·558	...	390·344	...	391·129	...	391·915	...	124
125	392·700	...	...	...	394·271	...	...	...	125
126	395·842	...	...	...	397·412	...	...	...	126
127	398·983	...	...	...	400·554	...	...	...	127
128	402·125	...	...	...	403 696	...	...	...	128
129	405·266	...	...	...	406·837	...	...	...	129
130	408·408	...	...	...	409·979	...	...	...	130
131	411·550	...	...	...	413·120	...	...	...	131
132	414·691	...	...	...	416·262	...	...	...	132

Table of the Circumferences of Circles—Cont.

Diameters.	Circumferences. ·0	·⅛	·¼	·⅜	·½	·⅝	·¾	·⅞	Diameters.
33	417·833	...	...	...	419·404	...	...	...	133
34	420·974	...	...	...	422·545	...	...	...	134
35	424·116	...	...	...	425·687	...	...	...	135
36	427·258	...	...	...	428·828	...	...	...	136
37	430·399	...	...	...	431·970	...	...	...	137
38	433·541	...	...	...	435·112	...	...	...	138
39	436·682	...	...	...	438·253	...	...	...	139
40	439·824	...	...	...	441·395	...	...	...	140
41	442·966	...	...	...	444·536	...	...	...	141
42	446·107	...	...	...	447·678	...	...	...	142
43	449·249	...	...	...	450·820	...	...	...	143
44	452·390	...	...	...	453·961	...	...	...	144
45	455·532	...	...	...	457·103	...	...	...	145
46	458·674	...	...	...	460·244	...	...	...	146
47	461·815	...	...	...	463·386	...	...	...	147
48	464·957	...	...	...	466·528	...	...	...	148
49	468·098	...	...	...	469·669	...	...	...	149
50	471·240	...	...	...	472·811	...	...	...	150

Table of Squares, Cubes, Square Roots, Cube Roots, and Reciprocals of all Integer Numbers from 1 to 2200.

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1	1	1	1·0000000	1·0000000	1·000000000
2	4	8	1·4142136	1·2599210	·500000000
3	9	27	1·7320508	1·4422496	·333333333
4	16	64	2·0000000	1·5874011	·250000000
5	25	125	2·2360680	1·7099759	·200000000
6	36	216	2·4494897	1·8171206	·166666667
7	49	343	2·6457513	1·9129312	·142857143
8	64	512	2·8284271	2·0000000	·125000000
9	81	729	3·0000000	2·0800837	·111111111
10	100	1000	3·1622777	2·1544347	·100000000
11	121	1331	3·3166248	2·2239801	·090909091
12	144	1728	3·4641016	2·2894286	·083333333
13	169	2197	3·6055513	2·3513347	·076923077
14	196	2744	3·7416574	2·4101422	·071428571
15	225	3375	3·8729833	2·4662121	·066666667
16	256	4096	4·0000000	2·5198421	·062500000
17	289	4913	4·1231056	2·5712816	·058823529
18	324	5832	4·2426407	2·6207414	·055555556
19	361	6859	4·3588989	2·6684016	·052631579
20	400	8000	4·4721360	2·7144177	·050000000
21	441	9261	4·5825757	2·7589243	·047619048
22	484	10648	4·6904158	2·8020393	·045454545
23	529	12167	4·7958315	2·8438670	·043478261
24	576	13824	4·8989795	2·8844991	·041666667
25	625	15625	5·0000000	2·9240177	·040000000
26	676	17576	5·0990195	2·9624960	·038461538
27	729	19683	5·1961524	3·0000000	·037037037
28	784	21952	5·2915026	3·0365889	·035714286
29	841	24389	5·3851648	3·0723168	·034482759
30	900	27000	5·4772256	3·1072325	·033333333
31	961	29791	5·5677644	3·1413806	·032258065
32	1024	32768	5·6568542	3·1748021	·031250000
33	1089	35937	5·7445626	3·2075343	·030303030
34	1156	39304	5·8309519	3·2396118	·029411765
35	1225	42875	5·9160798	3·2710663	·028571429
36	1296	46656	6·0000000	3·3019272	·027777778
37	1369	50653	6·0827625	3·3322218	·027027027
38	1444	54872	6·1644140	3·3619754	·026315789
39	1521	59319	6·2449980	3·3912114	·025641026
40	1600	64000	6·3245553	3·4199519	·025000000
41	1681	68921	6·4031242	3·4482172	·024390244
42	1764	74088	6·4807407	3·4760266	·023809524
43	1849	79507	6·5574385	3·5033981	·023255814
44	1936	85184	6·6332496	3·5303483	·022727273
45	2025	91125	6·7082039	3·5568933	·022222222

No.	Square	Cube	Square Root	Cube Root	Reciprocal
46	2116	97336	6·7823300	3·5830479	·021739130
47	2209	103823	6·8556546	3·6088261	·021276600
48	2304	110592	6·9282032	3·6342411	·020833333
49	2401	117649	7·0000000	3·6593057	·020408163
50	2500	125000	7·0710678	3·6840314	·020000000
51	2601	132651	7·1414284	3·7084298	·019607843
52	2704	140608	7·2111026	3·7325111	·019230769
53	2809	148877	7·2801099	3·7562858	·018867925
54	2916	157464	7·3484692	3·7797631	·018518519
55	3025	166375	7·4161985	3·8029525	·018181818
56	3136	175616	7·4833148	3·8258624	·017857143
57	3249	185193	7·5498344	3·8485011	·017543860
58	3364	195112	7·6157731	3·8708766	·017241379
59	3481	205379	7·6811457	3·8929965	·016949153
60	3600	216000	7·7459667	3·9148676	·016666667
61	3721	226981	7·8102497	3·9364972	·016393443
62	3844	238328	7·8740079	3·9578915	·016129032
63	3969	250047	7·9372539	3·9790571	·015873016
64	4096	262144	8·0000000	4·0000000	·015625000
65	4225	274625	8·0622577	4·0207256	·015384615
66	4356	287496	8·1240384	4·0412401	·015151515
67	4489	300763	8·1853528	4·0615480	·014925373
68	4624	314432	8·2462113	4·0816551	·014705882
69	4761	328509	8·3066239	4·1015661	·014492754
70	4900	343000	8·3666003	4·1212853	·014285714
71	5041	357911	8·4261498	4·1408178	·014084507
72	5184	373248	8·4852814	4·1601676	·013888889
73	5329	389017	8·5440037	4·1793392	·013698630
74	5476	405224	8·6023253	4·1983364	·013513514
75	5625	421875	8·6602540	4·2171633	·013333333
76	5776	438976	8·7177979	4·2358236	·013157895
77	5929	456533	8·7749644	4·2543210	·012987013
78	6084	474552	8·8317609	4·2726586	·012820513
79	6241	493039	8·8881944	4·2908404	·012658228
80	6400	512000	8·9442719	4·3088695	·012500000
81	6561	531441	9·0000000	4·3267487	·012345679
82	6724	551368	9·0553851	4·3444815	·012195122
83	6889	571787	9·1104336	4·3620707	·012048193
84	7056	592704	9·1651514	4·3795191	·011904762
85	7225	614125	9·2195445	4·3968296	·011764706
86	7396	636056	9·2736185	4·4140049	·011627907
87	7569	658503	9·3273791	4·4310476	·011494253
88	7744	681472	9·3808315	4·4479602	·011363636
89	7921	704969	9·4339811	4·4647451	·011235955
90	8100	729000	9·4868330	4·4814047	·011111111
91	8281	753571	9·5393920	4·4979414	·010989011
92	8464	778688	9·5916630	4·5143574	·010869565
93	8649	804357	9·6436508	4·5306549	·010752688
94	8836	830584	9·6953597	4·5468359	·010638298

No.	Square	Cube	Square Root	Cube Root	Reciprocal
95	9025	857375	9·7467943	4·5629026	·010526316
96	9216	884736	9·7979590	4·5788570	·010416667
97	9409	912673	9·8488578	4·5947009	·010309278
98	9604	941192	9·8994949	4·6104363	·010204082
99	9801	970299	9·9498744	4·6260650	·010101010
100	10000	1000000	10·0000000	4·6415888	·010000000
101	10201	1030301	10·0498756	4·6570095	·009900990
102	10404	1061208	10·0995049	4·6723287	·009803922
103	10609	1092727	10·1488916	4·6875482	·009708738
104	10816	1124864	10·1980390	4·7026694	·009615385
105	11025	1157625	10·2469508	4·7176940	·009523810
106	11236	1191016	10·2956301	4·7326235	·009433962
107	11449	1225043	10·3440804	4·7474594	·009345794
108	11664	1259712	10·3923048	4·7622032	·009259259
109	11881	1295029	10·4403065	4·7768562	·009174312
110	12100	1331000	10·4880885	4·7914199	·009090909
111	12321	1367631	10·5356538	4·8058955	·009009009
112	12544	1404928	10·5830052	4·8202845	·008928571
113	12769	1442897	10·6301458	4·8345881	·008849558
114	12996	1481544	10·6770783	4·8488076	·008771930
115	13225	1520875	10·7238053	4·8629442	·008695652
116	13456	1560896	10·7703296	4·8769990	·008620690
117	13689	1601613	10·8166538	4·8909732	·008547009
118	13924	1643032	10·8627805	4·9048681	·008474576
119	14161	1685159	10·9087121	4·9186847	·008403361
120	14400	1728000	10·9544512	4·9324242	·008333333
121	14641	1771561	11·0000000	4·9460874	·008264463
122	14884	1815848	11·0453610	4·9596757	·008196721
123	15129	1860867	11·0905365	4·9731898	·008130081
124	15376	1906624	11·1355287	4·9866310	·008064516
125	15625	1953125	11·1803399	5·0000000	·008000000
126	15876	2000376	11·2249722	5·0132979	·007936508
127	16129	2048383	11·2694277	5·0265257	·007874016
128	16384	2097152	11·3137085	5·0396842	·007812500
129	16641	2146689	11·3578167	5·0527743	·007751938
130	16900	2197000	11·4017543	5·0657970	·007692308
131	17161	2248091	11·4455231	5·0787531	·007633588
132	17424	2299968	11·4891253	5·0916434	·007575758
133	17689	2352637	11·5325626	5·1044687	·007518797
134	17956	2406104	11·5758369	5·1172299	·007462687
135	18225	2460375	11·6189500	5·1299278	·007407407
136	18496	2515456	11·6619038	5·1425632	·007352941
137	18769	2571353	11·7046999	5·1551367	·007299270
138	19044	2628072	11·7473401	5·1676493	·007246377
139	19321	2685619	11·7898261	5·1801015	·007194245
140	19600	2744000	11·8321596	5·1924941	·007142857
141	19881	2803221	11·8743422	5·2048279	·007092199
142	20164	2863288	11·9163753	5·2171034	·007042254
143	20449	2924207	11·9582607	5·2293215	·006993007

No.	Square	Cube	Square Root	Cube Root	Reciprocal
144	20736	2985984	12·0000000	5·2414828	·006944444
145	21025	3048625	12·0415946	5·2535879	·006896552
146	21316	3112136	12·0830460	5·2656374	·006849315
147	21609	3176523	12·1243557	5·2776321	·006802721
148	21904	3241792	12·1655251	5·2895725	·006756757
149	22201	3307949	12·2065556	5·3014592	·006711409
150	22500	3375000	12·2474487	5·3132928	·006666667
151	22801	3442951	12·2882057	5·3250740	·006622517
152	23104	3511808	12·3288280	5·3368033	·006578947
153	23409	3581577	12·3693169	5·3484812	·006535948
154	23716	3652264	12·4096736	5·3601084	·006493506
155	24025	3723875	12·4498996	5·3716854	·006451613
156	24336	3796416	12·4899960	5·3832126	·006410256
157	24649	3869893	12·5299641	5·3946907	·006369427
158	24964	3944312	12·5698051	5·4061202	·006329114
159	25281	4019679	12·6095202	5·4175015	·006289308
160	25600	4096000	12·6491106	5·4288352	·006250000
161	25921	4173281	12·6885775	5·4401218	·006211180
162	26244	4251528	12·7279221	5·4513618	·006172840
163	26569	4330747	12·7671453	5·4625556	·006134969
164	26896	4410944	12·8062485	5·4737037	·006097561
165	27225	4492125	12·8452326	5·4848066	·006060606
166	27556	4574296	12·8840987	5·4958647	·006024096
167	27889	4657463	12·9228480	5·5068784	·005988024
168	28224	4741632	12·9614814	5·5178484	·005952381
169	28561	4826809	13·0000000	5·5287748	·005917160
170	28900	4913000	13·0384048	5·5396583	·005882353
171	29241	5000211	13·0766968	5·5504991	·005847953
172	29584	5088448	13·1148770	5·5612978	·005813953
173	29929	5177717	13·1529464	5·5720546	·005780347
174	30276	5268024	13·1909060	5·5827702	·005747126
175	30625	5359375	13·2287566	5·5934447	·005714286
176	30976	5451776	13·2664992	5·6040787	·005681818
177	31329	5545233	13·3041347	5·6146724	·005649718
178	31684	5639752	13·3416641	5·6252263	·005617978
179	32041	5735339	13·3790882	5·6357408	·005586592
180	32400	5832000	13·4164079	5·6462162	·005555556
181	32761	5929741	13·4536240	5·6566528	·005524862
182	33124	6028568	13·4907376	5·6670511	·005494505
183	33489	6128487	13·5277493	5·6774114	·005464481
184	33856	6229504	13·5646600	5·6877340	·005434783
185	34225	6331625	13·6014705	5·6980192	·005405405
186	34596	6434856	13·6381817	5·7082675	·005376344
187	34969	6539203	13·6747943	5·7184791	·005347594
188	35344	6644672	13·7113092	5·7286543	·005319149
189	35721	6751269	13·7477271	5·7387936	·005291005
190	36100	6859000	13·7840488	5·7488971	·005263158
191	36481	6967871	13·8202750	5·7589652	·005235602
192	36864	7077888	13·8564065	5·7689982	·005208333

No.	Square	Cube	Square Root	Cube Root	Reciprocal
193	37249	7189057	13·8924440	5·7789966	·005181347
194	37636	7301384	13·9283883	5·7889604	·005154639
195	38025	7414875	13·9642400	5·7988900	·005128205
196	38416	7529536	14·0000000	5·8087857	·005102041
197	38809	7645373	14·0356688	5·8186479	·005076142
198	39204	7762392	14·0712473	5·8284767	·005050505
199	39601	7880599	14·1067360	5·8382725	·005025126
200	40000	8000000	14·1421356	5·8480355	·005000000
201	40401	8120601	14·1774469	5·8577660	·004975124
202	40804	8242408	14·2126704	5·8674643	·004950495
203	41209	8365427	14·2478068	5·8771307	·004926108
204	41616	8489664	14·2828569	5·8867653	·004901961
205	42025	8615125	14·3178211	5·8963685	·004878049
206	42436	8741816	14·3527001	5·9059406	·004854369
207	42849	8869743	14·3874946	5·9154817	·004830918
208	43264	8998912	14·4222051	5·9249921	·004807692
209	43681	9129329	14·4568323	5·9344721	·004784689
210	44100	9261000	14·4913767	5·9439220	·004761905
211	44521	9393931	14·5258390	5·9533418	·004739336
212	44944	9528128	14·5602198	5·9627320	·004716981
213	45369	9663597	14·5945195	5·9720926	·004694836
214	45796	9800344	14·6287388	5·9814240	·004672897
215	46225	9938375	14·6628783	5·9907264	·004651163
216	46656	10077696	14·6969385	6·0000000	·004629630
217	47089	10218313	14·7309199	6·0092450	·004608295
218	47524	10360232	14·7648231	6·0184617	·004587156
219	47961	10503459	14·7986486	6·0276502	·004566210
220	48400	10648000	14·8323970	6·0368107	·004545455
221	48841	10793861	14·8660687	6·0459435	·004524887
222	49284	10941048	14·8996644	6·0550489	·004504505
223	49729	11089567	14·9331845	6·0641270	·004484305
224	50176	11239424	14·9666295	6·0731779	·004464286
225	50625	11390625	15·0000000	6·0822020	·004444444
226	51076	11543176	15·0332964	6·0911994	·004424779
227	51529	11697083	15·0665192	6·1001702	·004405286
228	51984	11852352	15·0996689	6·1091147	·004385965
229	52441	12008989	15·1327460	6·1180332	·004366812
230	52900	12167000	15·1657509	6·1269257	·004347826
231	53361	12326391	15·1986842	6·1357924	·004329004
232	53824	12487168	15·2315462	6·1446337	·004310345
233	54289	12649337	15·2643375	6·1534495	·004291845
234	54756	12812904	15·2970585	6·1622401	·004273504
235	55225	12977875	15·3297097	6·1710058	·004255319
236	55696	13144256	15·3622915	6·1797466	·004237288
237	56169	13312053	15·3948043	6·1884628	·004219409
238	56644	13481272	15·4272486	6·1971544	·004201681
239	57121	13651919	15·4596248	6·2058218	·004184100
240	57600	13824000	15·4919334	6·2144650	·004166667
241	58081	13997521	15·5241747	6·2230843	·004149378

No.	Square	Cube	Square Root	Cube Root	Reciprocal
242	58564	14172488	15·5563492	6·2316797	·004132231
243	59049	14348907	15·5884573	6·2402515	·004115226
244	59536	14526784	15·6204994	6·2487998	·004098361
245	60025	14706125	15·6524758	6·2573248	·004081633
246	60516	14886936	15·6843871	6·2658266	·004065041
247	61009	15069223	15·7162336	6·2743054	·004048583
248	61504	15252992	15·7480157	6·2827613	·004032258
249	62001	15438249	15·7797338	6·2911946	·004016064
250	62500	15625000	15·8113883	6·2996053	·004000000
251	63001	15813251	15·8429795	6·3079935	·003984064
252	63504	16003008	15·8745079	6·3163596	·003968254
253	64009	16194277	15·9059737	6·3247035	·003952569
254	64516	16387064	15·9373775	6·3330256	·003937008
255	65025	16581375	15·9687194	6·3413257	·003921569
256	65536	16777216	16·0000000	6·3496042	·003906250
257	66049	16974593	16·0312195	6·3578611	·003891051
258	66564	17173512	16·0623784	6·3660968	·003875969
259	67081	17373979	16·0934769	6·3743111	·003861004
260	67600	17576000	16·1245155	6·3825043	·003846154
261	68121	17779581	16·1554944	6·3906765	·003831418
262	68644	17984728	16·1864141	6·3988279	·003816794
263	69169	18191447	16·2172747	6·4069585	·003802281
264	69696	18399744	16·2480768	6·4150687	·003787879
265	70225	18609625	16·2788206	6·4231583	·003773585
266	70756	18821096	16·3095064	6·4312276	·003759398
267	71289	19034163	16·3401346	6·4392767	·003745318
268	71824	19248832	16·3707055	6·4473057	·003731343
269	72361	19465109	16·4012195	6·4553148	·003717472
270	72900	19683000	16·4316767	6·4633041	·003703704
271	73441	19902511	16·4620776	6·4712736	·003690037
272	73984	20123648	16·4924225	6·4792236	·003676471
273	74529	20346417	16·5227116	6·4871541	·003663004
274	75076	20570824	16·5529454	6·4950653	·003649635
275	75625	20796875	16·5831240	6·5029572	·003636364
276	76176	21024576	16·6132477	6·5108300	·003623188
277	76729	21253933	16·6433170	6·5186839	·003610108
278	77284	21484952	16·6733320	6·5265189	·003597122
279	77841	21717639	16·7032931	6·5343351	·003584229
280	78400	21952000	16·7332005	6·5421326	·003571429
281	78961	22188041	16·7630546	6·5499116	·003558719
282	79524	22425768	16·7928556	6·5576722	·003546099
283	80089	22665187	16·8226038	6·5654144	·003533569
284	80656	22906304	16·8522995	6·5731385	·003521127
285	81225	23149125	16·8819430	6·5808443	·003508772
286	81796	23393656	16·9115345	6·5885323	·003496503
287	82369	23639903	16·9410743	6·5962023	·003484321
288	82944	23887872	16·9705627	6·6038545	·003472222
289	83521	24137569	17·0000000	6·6114890	·003460208
290	84100	24389000	17·0293864	6·6191060	·003448276

No.	Square	Cube	Square Root	Cube Root	Reciprocal
291	84681	24642171	17·0587221	6·6267054	·003436426
292	85264	24897088	17·0880075	6·6342874	·003424658
293	85849	25153757	17·1172428	6·6418522	·003412969
294	86436	25412184	17·1464282	6·6493998	·003401361
295	87025	25672375	17·1755640	6·6569302	·003389831
296	87616	25934336	17·2046505	6·6644437	·003378378
297	88209	26198073	17·2336879	6·6719403	·003367003
298	88804	26463592	17·2626765	6·6794200	·003355705
299	89401	26730899	17·2916165	6·6868831	·003344482
300	90000	27000000	17·3205081	6·6943295	·003333333
301	90601	27270901	17·3493516	6·7017593	·003322259
302	91204	27543608	17·3781472	6·7091729	·003311258
303	91809	27818127	17·4068952	6·7165700	·003300330
304	92416	28094464	17·4355958	6·7239508	·003289474
305	93025	28372625	17·4642492	6·7313155	·003278689
306	93636	28652616	17·4928557	6·7386641	·003267974
307	94249	28934443	17·5214155	6·7459967	·003257329
308	94864	29218112	17·5499288	6·7533134	·003246753
309	95481	29503629	17·5783958	6·7606143	·003236246
310	96100	29791000	17·6068169	6·7678995	·003225806
311	96721	30080231	17·6351921	6·7751690	·003215434
312	97344	30371328	17·6635217	6·7824229	·003205128
313	97969	30664297	17·6918060	6·7896613	·003194888
314	98596	30959144	17·7200451	6·7968844	·003184713
315	99225	31255875	17·7482393	6·8040921	·003174603
316	99856	31554496	17·7763888	6·8112847	·003164557
317	100489	31855013	17·8044938	6·8184620	·003154574
318	101124	32157432	17·8325545	6·8256242	·003144654
319	101761	32461759	17·8605711	6·8327714	·003134796
320	102400	32768000	17·8885438	6·8399037	·003125000
321	103041	32076161	17·9164729	6·8470213	·003115265
322	103684	33386248	17·9443584	6·8541240	·003105590
323	104329	33698267	17·9722008	6·8612120	·003095975
324	104976	34012224	18·0000000	6·8682855	·003086420
325	105625	34328125	18·0277564	6·8753443	·003076923
326	106276	34645976	18·0554701	6·8823888	·003067485
327	106929	34965783	18·0831413	6·8894188	·003058104
328	107584	35287552	18·1107703	6·8964345	·003048780
329	108241	35611289	18·1383571	6·9034359	·003039514
330	108900	35937000	18·1659021	6·9104232	·003030303
331	109561	36264691	18·1934054	6·9173964	·003021148
332	110224	36594368	18·2208672	6·9243556	·003012048
333	110889	36926037	18·2482876	6·9313008	·003003003
334	111556	37259704	18·2756669	6·9382321	·002994012
335	112225	37595375	18·3030052	6·9451496	·002985075
336	112896	37933056	18·3303028	6·9520533	·002976190
337	113569	38272753	18·3575598	6·9589434	·002967359
338	114244	38614472	18·3847763	6·9658198	·002958580
339	114921	38958219	18·4119526	6·9726826	·002949853

No.	Square	Cube	Square Root	Cube Root	Reciprocal
340	115600	39304000	18·4390889	6·9795321	·002941176
341	116281	39651821	18·4661853	6·9863681	·002932551
342	116964	40001688	18·4932420	6·9931906	·002923977
343	117649	40353607	18·5202592	7·0000000	·002915452
344	118336	40707584	18·5472370	7·0067962	·002906977
345	119025	41063625	18·5741756	7·0135791	·002898551
346	119716	41421736	18·6010752	7·0203490	·002890173
347	120409	41781923	18·6279360	7·0271058	·002881844
348	121104	42144192	18·6547581	7·0338497	·002873563
349	121801	42508549	18·6815147	7·0405806	·002865330
350	122500	42875000	18·7082869	7·0472987	·002857143
351	123201	43243551	18·7349940	7·0540041	·002849003
352	123904	43614208	18·7616630	7·0606967	·002840909
353	124609	43986977	18·7882942	7·0673767	·002832861
354	125316	44361864	18·8148877	7·0740440	·002824859
355	126025	44738875	18·8414437	7·0806988	·002816901
356	126736	45118016	18·8679623	7·0873411	·002808989
357	127449	45499293	18·8944436	7·0939709	·002801120
358	128164	45882712	18·9208879	7·1005885	·002793296
359	128881	46268279	18·9472953	7·1071937	·002785515
360	129600	46656000	18·9736660	7·1137866	·002777778
361	130321	47045881	19·0000000	7·1203674	·002770083
362	131044	47437928	19·0262976	7·1269360	·002762431
363	131769	47832147	19·0525589	7·1334925	·002754821
364	132496	48228544	19·0787840	7·1400370	·002747253
365	133225	48627125	19·1049732	7·1465695	·002739726
366	133956	49027896	19·1311265	7·1530901	·002732240
367	134689	49430863	19·1572441	7·1595988	·002724796
368	135424	49836032	19·1833261	7·1660957	·002717391
369	136161	50243409	19·2093727	7·1725809	·002710027
370	136900	50653000	19·2353841	7·1790544	·002702703
371	137641	51064811	19·2613603	7·1855162	·002695418
372	138384	51478848	19·2873015	7·1919663	·002688172
373	139129	51895117	19·3132079	7·1984050	·002680965
374	139876	52313624	19·3390796	7·2048322	·002673797
375	140625	52734375	19·3649167	7·2112479	·002666667
376	141376	53157376	19·3907194	7·2176522	·002659574
377	142129	53582633	19·4164878	7·2240450	·002652520
378	142884	54010152	19·4422221	7·2304268	·002645503
379	143641	54439939	19·4679223	7·2367972	·002638522
380	144400	54872000	19·4935887	7·2431565	·002631579
381	145161	55306341	19·5192213	7·2495045	·002624672
382	145924	55742968	19·5448203	7·2558415	·002617801
383	146689	56181887	19·5703858	7·2621675	·002610966
384	147456	56623104	19·5959179	7·2684824	·002604167
385	148225	57066625	19·6214169	7·2747864	·002597403
386	148996	57512456	19·6468827	7·2810794	·002590674
387	149769	57960603	19·6723156	7·2873617	·002583979
388	150544	58411072	19·6977156	7·2936330	·002577320

No.	Square	Cube	Square Root	Cube Root	Reciprocal
389	151321	58863869	19·7230829	7·2998936	·002570694
390	152100	59319000	19·7484177	7·3061436	·002564103
391	152881	59776471	19·7737199	7·3123828	·002557545
392	153664	60236288	19·7989899	7·3186114	·002551020
393	154449	60698457	19·8242276	7·3248295	·002544529
394	155236	61162984	19·8494332	7·3310369	·002538071
395	156025	61629875	19·8746069	7·3372339	·002531646
396	156816	62099136	19·8997487	7·3434205	·002525253
397	157609	62570773	19·9248588	7·3495966	·002518892
398	158404	63044792	19·9499373	7·3557624	·002512563
399	159201	63521199	19·9749844	7·3619178	·002506266
400	160000	64000000	20·0000000	7·3680630	·002500000
401	160801	64481201	20·0249844	7·3741979	·002493766
402	161604	64964808	20·0499377	7·3803227	·002487562
403	162409	65450827	20·0748599	7·3864373	·002481390
404	163216	65939264	20·0997512	7·3925418	·002475248
405	164025	66430125	20·1246118	7·3986363	·002469136
406	164836	66923416	20·1494417	7·4047206	·002463054
407	165649	67419143	20·1742410	7·4107950	·002457002
408	166464	67917312	20·1990099	7·4168595	·002450980
409	167281	68417929	20·2237484	7·4229142	·002444988
410	168100	68921000	20·2484567	7·4289589	·002439024
411	168921	69426531	20·2731349	7·4349938	·002433090
412	169744	69934528	20·2977831	7·4410189	·002427184
413	170569	70444997	20·3224014	7·4470342	·002421308
414	171396	70957944	20·3469899	7·4530399	·002415459
415	172225	71473375	20·3715488	7·4590359	·002409639
416	173056	71991296	20·3960781	7·4650223	·002403846
417	173889	72511713	20·4205779	7·4709991	·002398082
418	174724	73034632	20·4450483	7·4769664	·002392344
419	175561	73560059	20·4694895	7·4829242	·002386635
420	176400	74088000	20·4939015	7·4888724	·002380952
421	177241	74618461	20·5182845	7·4948113	·002375297
422	178084	75151448	20·5426386	7·5007406	·002369668
423	178929	75686967	20·5669638	7·5066607	·002364066
424	179776	76225024	20·5912603	7·5125715	·002358491
425	180625	76765625	20·6155281	7·5184730	·002352941
426	181476	77308776	20·6397674	7·5243652	·002347418
427	182329	77854483	20·6639783	7·5302482	·002341920
428	183184	78402752	20·6881609	7·5361221	·002336449
429	184041	78953589	20·7123152	7·5419867	·002331002
430	184900	79507000	20·7364414	7·5478423	·002325581
431	185761	80062991	20·7605395	7·5536888	·002320186
432	186624	80621568	20·7846097	7·5595263	·002314815
433	187489	81182737	20·8086520	7·5653548	·002309469
434	188356	81746504	20·8326667	7·5711743	·002304147
435	189225	82312875	20·8566536	7·5769849	·002298851
436	190096	82881856	20·8806130	7·5827865	·002293578
437	190969	83453453	20·9045450	7·5885793	·002288330

No.	Square	Cube	Square Root	Cube Root	Reciprocal
438	191844	84027672	20·9284495	7·5943633	·002283105
439	192721	84604519	20·9523268	7·6001385	·002277004
440	193600	85184000	20·9761770	7·6059049	·002272727
441	194481	85766121	21·0000000	7·6116626	·002267574
442	195364	86350888	21·0237960	7·6174116	·002262443
443	196249	86938307	21·0475652	7·6231519	·002257336
444	197136	87528384	21·0713075	7·6288837	·002252252
445	198025	88121125	21·0950231	7·6346067	·002247191
446	198916	88716536	21·1187121	7·6403213	·002242152
447	199809	89314623	21·1423745	7·6460272	·002237136
448	200704	89915392	21·1660105	7·6517247	·002232143
449	201601	90518849	21·1896201	7·6574138	·002227171
450	202500	91125000	21·2132034	7·6630943	·002222222
451	203401	91733851	21·2367606	7·6687665	·002217295
452	204304	92345408	21·2602916	7·6744303	·002212389
453	205209	92959677	21·2837967	7·6800857	·002207506
454	206116	93576664	21·3072758	7·6857328	·002202643
455	207025	94196375	21·3307290	7·6913717	·002197802
456	207936	94818816	21·3541565	7·6970023	·002192982
457	208849	95443993	21·3775583	7·7026246	·002188184
458	209764	96071912	21·4009346	7·7082388	·002183406
459	210681	96702579	21·4242853	7·7138448	·002178649
460	211600	97336000	21·4476106	7·7194426	·002173913
461	212521	97972181	21·4709106	7·7250325	·002169197
462	213444	98611128	21·4941853	7·7306141	·002164502
463	214369	99252847	21·5174348	7·7361877	·002159827
464	215296	99897344	21·5406592	7·7417532	·002155172
465	216225	100544625	21·5638587	7·7473109	·002150538
466	217156	101194696	21·5870331	7·7528606	·002145923
467	218089	101847563	21·6101828	7·7584023	·002141328
468	219024	102503232	21·6333077	7·7639361	·002136752
469	219961	103161709	21·6564078	7·7694620	·002132196
470	220900	103823000	21·6794834	7·7749801	·002127660
471	221841	104487111	21·7025344	7·7804904	·002123142
472	222784	105154048	21·7255610	7·7859928	·002118644
473	223729	105823817	21·7485632	7·7914875	·002114165
474	224676	106496424	21·7715411	7·7969745	·002109705
475	225625	107171875	21·7944947	7·8024538	·002105263
476	226576	107850176	21·8174242	7·8079254	·002100840
477	227529	108531333	21·8403297	7·8133892	·002096436
478	228484	109215352	21·8632111	7·8188456	·002092050
479	229441	109902239	21·8860686	7·8242942	·002087683
480	230400	110592000	21·9089023	7·8297353	·002083333
481	231361	111284641	21·9317122	7·8351688	·002079002
482	232324	111980168	21·9544984	7·8405949	·002074689
483	233289	112678587	21·9772610	7·8460134	·002070393
484	234256	113379904	22·0000000	7·8514244	·002066116
485	235225	114084125	22·0227155	7·8568281	·002061856
486	236196	114791256	22·0454077	7·8622242	·002057613

No.	Square	Cube	Square Root	Cube Root	Reciprocal
487	237169	115501303	22·0680765	7·8676130	·002053388
488	238144	116214272	22·0907220	7·8729944	·002049180
489	239121	116930169	22·1133444	7·8783684	·002044990
490	240100	117649000	22·1359436	7·8837352	·002040816
491	241081	118370771	22·1585198	7·8890946	·002036660
492	242064	119095488	22·1810730	7·8944468	·002032520
493	243049	119823157	22·2036033	7·8997917	·002028398
494	244036	120553784	22·2261108	7·9051294	·002024291
495	245025	121287375	22·2485955	7·9104599	·002020202
496	246016	122023936	22·2710575	7·9157832	·002016129
497	247009	122763473	22·2934968	7·9210994	·002012072
498	248004	123505992	22·3159136	7·9264085	·002008032
499	249001	124251499	22·3383079	7·9317104	·002004008
500	250000	125000000	22·3606798	7·9370053	·002000000
501	251001	125751501	22·3830293	7·9422931	·001996008
502	252004	126506008	22·4053565	7·9475739	·001992032
503	253009	127263527	22·4276615	7·9528477	·001988072
504	254016	128024064	22·4499443	7·9581144	·001984127
505	255025	128787625	22·4722051	7·9633743	·001980198
506	256036	129554216	22·4944438	7·9686271	·001976285
507	257049	130323843	22·5166605	7·9738731	·001972387
508	258064	131096512	22·5388553	7·9791122	·001968504
509	259081	131872229	22·5610283	7·9843444	·001964637
510	260100	132651000	22·5831796	7·9895697	·001960784
511	261121	133432831	22·6053091	7·9947883	·001956947
512	262144	134217728	22·6274170	8·0000000	·001953125
513	263169	135005697	22·6495033	8·0052049	·001949318
514	264196	135796744	22·6715681	8·0104032	·001945525
515	265225	136590875	22·6936114	8·0155946	·001941748
516	266256	137388096	22·7156334	8·0207794	·001937984
517	267289	138188413	22·7376340	8·0259574	·001934236
518	268324	138991832	22·7596134	8·0311287	·001930502
519	269361	139798359	22·7815715	8·0362935	·001926782
520	270400	140608000	22·8035085	8·0414515	·001923077
521	271441	141420761	22·8254244	8·0466030	·001919386
522	272484	142236648	22·8473193	8·0517479	·001915709
523	273529	143055667	22·8691933	8·0568862	·001912046
524	274576	143877824	22·8910463	8·0620180	·001908397
525	275625	144703125	22·9128785	8·0671432	·001904762
526	276676	145531576	22·9346899	8·0722620	·001901141
527	277729	146363183	22·9564806	8·0773743	·001897533
528	278784	147197952	22·9782506	8·0824800	·001893939
529	279841	148035889	23·0000000	8·0875794	·001890359
530	280900	148877000	23·0217289	8·0926723	·001886792
531	281961	149721291	23·0434372	8·0977589	·001883239
532	283024	150568768	23·0651252	8·1028390	·001879699
533	284089	151419437	23·0867928	8·1079128	·001876173
534	285156	152273304	23·1084400	8·1129803	·001872659
535	286225	153130375	23·1300670	8·1180414	·001869159

No.	Square	Cube	Square Root	Cube Root	Reciprocal
536	287296	153990656	23·1516738	8·1230962	·001865672
537	288369	154854153	23·1732605	8·1281447	·001862197
538	289444	155720872	23·1948270	8·1331870	·001858736
539	290521	156590819	23·2163735	8·1382230	·001855288
540	291600	157464000	23·2379001	8·1432529	·001851852
541	292681	158340421	23·2594067	8·1482765	·001848429
542	293764	159220088	23·2808935	8·1532939	·001845018
543	294849	160103007	23·3023604	8·1583051	·001841621
544	295936	160989184	23·3238076	8·1633102	·001838235
545	297025	161878625	23·3452351	8·1683092	·001834862
546	298116	162771336	23·3666429	8·1733020	·001831502
547	299209	163667323	23·3880311	8·1782888	·001828154
548	300304	164566592	23·4093998	8·1832695	·001824818
549	301401	165469149	23·4307490	8·1882441	·001821494
550	302500	166375000	23·4520788	8·1932127	·001818182
551	303601	167284151	23·4733892	8·1981753	·001814882
552	304704	168196608	23·4946802	8·2031319	·001811594
553	305809	169112377	23·5159520	8·2080825	·001808318
554	306916	170031464	23·5372046	8·2130271	·001805054
555	308025	170953875	23·5584380	8·2179657	·001801802
556	309136	171879616	23·5796522	8·2228985	·001798561
557	310249	172808693	23·6008474	8·2278254	·001795332
558	311364	173741112	23·6220236	8·2327463	·001792115
559	312481	174676879	23·6431808	8·2376614	·001788909
560	313600	175616000	23·6643191	8·2425706	·001785714
561	314721	176558481	23·6854386	8·2474740	·001782531
562	315844	177504328	23·7065392	8·2523715	·001779359
563	316969	178453547	23·7276210	8·2572633	·001776199
564	318096	179406144	23·7486842	8·2621492	·001773050
565	319225	180362125	23·7697286	8·2670294	·001769912
566	320356	181321496	23·7907545	8·2719039	·001766784
567	321489	182284263	23·8117618	8·2767726	·001763668
568	322624	183250432	23·8327506	8·2816355	·001760563
569	323761	184220009	23·8537209	8·2864928	·001757469
570	324900	185193000	23·8746728	8·2913444	·001754386
571	326041	186169411	23·8956063	8·2961903	·001751313
572	327184	187149248	23·9165215	8·3010304	·001748252
573	328329	188132517	23·9374184	8·3058651	·001745201
574	329476	189119224	23·9582971	8·3106941	·001742160
575	330625	190109375	23·9791576	8·3155175	·001739130
576	331776	191102976	24·0000000	8·3203353	·001736111
577	332929	192100033	24·0208243	8·3251475	·001733102
578	334084	193100552	24·0416306	8·3299542	·001730104
579	335241	194104539	24·0624188	8·3347553	·001727116
580	336400	195112000	24·0831891	8·3395509	·001724138
581	337561	196122941	24·1039416	8·3443410	·001721170
582	338724	197137368	24·1246762	8·3491256	·001718213
583	339889	198155287	24·1453929	8·3539047	·001715266
584	341056	199176704	24·1660919	8·3586784	·001712329

No.	Square	Cube	Square Root	Cube Root	Reciprocal
585	342225	200201625	24·1867732	8·3634466	·001709402
586	343396	201230056	24·2074369	8·3682095	·001706485
587	344569	202262003	24·2280829	8·3729668	·001703578
588	345744	203297472	24·2487113	8·3777188	·005700680
589	346921	204336469	24·2693222	8·3824653	·001697793
590	348100	205379000	24·2899156	8·3872065	·001694915
591	349281	206425071	24·3104916	8·3919423	·001692047
592	350464	207474688	24·3310501	8·3966729	·001689189
593	351649	208527857	24·3515913	8·4013981	·001686341
594	352836	209584584	24·3721152	8·4061180	·001683502
595	354025	210644875	24·3926218	8·4108326	·001680672
596	355216	211708736	24·4131112	8·4155419	·001677852
597	356409	212776173	24·4335834	8·4202460	·001675042
598	357604	213847192	24·4540385	8·4249448	·001672241
599	358801	214921799	24·4744765	8·4296383	·001669449
600	360000	216000000	24·4948974	8·4343267	·001666667
601	361201	217081801	24·5153013	8·4390098	·001663894
602	362404	218167208	24·5356883	8·4436877	·001661130
603	363609	219256227	24·5560583	8·4483605	·001658375
604	364816	220348864	24·5764115	8·4530281	·001655629
605	366025	221445125	24·5967478	8·4576906	·001652893
606	367236	222545016	24·6170673	8·4623479	·001650165
607	368449	223648543	24·6373700	8·4670000	·001647446
608	369664	224755712	24·6576560	8·4716471	·001644737
609	370881	225866529	24·6779254	8·4762892	·001642036
610	372100	226981000	24·6981781	8·4809261	·001639344
611	373321	228099131	24·7184142	8·4855579	·001636661
612	374544	229220928	24·7386338	8·4901848	·001633987
613	375769	230346397	24·7588368	8·4948065	·001631321
614	376996	231475544	24·7790234	8·4994233	·001628664
615	378225	232608375	24·7991935	8·5040350	·001626016
616	379456	233744896	24·8193473	8·5086417	·001623377
617	380689	234885113	24·8394847	8·5132435	·001620746
618	381924	236029032	24·8596058	8·5178403	·001618123
619	383161	237176659	24·8797106	8·5224321	·001615509
620	384400	238328000	24·8997992	8·5270189	·001612903
621	385641	239483061	24·9198716	8·5316009	·001610306
622	386884	240641848	24·9399278	8·5361780	·001607717
623	388129	241804367	24·9599679	8·5407501	·001605136
624	389376	242970624	24·9799920	8·5453173	·001602564
625	390625	244140625	25·0000000	8·5498797	·001600000
626	391876	245314376	25·0199920	8·5544372	·001597444
627	393129	246491883	25·0399681	8·5589899	·001594896
628	394384	247673152	25·0599282	8·5635377	·001592357
629	395641	248858189	25·0798724	8·5680807	·001589825
630	396900	250047000	25·0998008	8·5726189	·001587302
631	398161	251239591	25·1197134	8·5771523	·001584786
632	399424	252435968	25·1396102	8·5816809	·001582278
633	400689	253636137	25·1594913	8·5862047	·001579779

No.	Square	Cube	Square Root	Cube Root	Reciprocal
634	401956	254840104	25·1793566	8·5907238	·001577287
635	403225	256047875	25·1992063	8·5952380	·001574803
636	404496	257259456	25·2190404	8·5997476	·001572327
637	405769	258474853	25·2388589	8·6042525	·001569859
638	407044	259694072	25·2586619	8·6087526	·001567398
639	408321	260917119	25·2784493	8·6132480	·001564945
640	409600	262144000	25·2982213	8·6177388	·001562500
641	410881	263374721	25·3179778	8·6222248	·001560062
642	412164	264609288	25·3377189	8·6267063	·001557632
643	413449	265847707	25·3574447	8·6311830	·001555210
644	414736	267089984	25·3771551	8·6356551	·001552795
645	416025	268336125	25·3968502	8·6401226	·001550388
646	417316	269586136	25·4165301	8·6445855	·001547988
647	418609	270840023	25·4361947	8·6490437	·001545595
648	419904	272097792	25·4558441	8·6534974	·001543210
649	421201	273359449	25·4754784	8·6579465	·001540832
650	422500	274625000	25·4950976	8·6623911	·001538462
651	423801	275894451	25·5147016	8·6668310	·001536098
652	425104	277167808	25·5342907	8·6712665	·001533742
653	426409	278445077	25·5538647	8·6756974	·001531394
654	427716	279726264	25·5734237	8·6801237	·001529052
655	429025	281011375	25·5929678	8·6845456	·001526718
656	430336	282300416	25·6124969	8·6889630	·001524390
657	431649	283593393	25·6320112	8·6933759	·001522070
658	432964	284890312	25·6515107	8·6977843	·001519757
659	434281	286191179	25·6709953	8·7021882	·001517451
660	435600	287496000	25·6904652	8·7065877	·001515152
661	436921	288804781	25·7099203	8·7109827	·001512859
662	438244	290117528	25·7293607	8·7153734	·001510574
663	439569	291434247	25·7487864	8·7197596	·001508296
664	440896	292754944	25·7681975	8·7241414	·001506024
665	442225	294079625	25·7875939	8·7285187	·001503759
666	443556	295408296	25·8069758	8·7328918	·001501502
667	444889	296740963	25·8263431	8·7372604	·001499250
668	446224	298077632	25·8456960	8·7416246	·001497006
669	447561	299418309	25·8650343	8·7459846	·001494768
670	448900	300763000	25·8843582	8·7503401	·001492537
671	450241	302111711	25·9036677	8·7546913	·001490313
672	451584	303464448	25·9229628	8·7590383	·001488095
673	452929	304821217	25·9422435	8·7633809	·001485884
674	454276	306182024	25·9615100	8·7677192	·001483680
675	455625	307546875	25·9807621	8·7720532	·001481481
676	456976	308915776	26·0000000	8·7763830	·001479290
677	458329	310288733	26·0192237	8·7807084	·001477105
678	459684	311665752	26·0384331	8·7850296	·001474926
679	461041	313046839	26·0576284	8·7893466	·001472754
680	462400	314432000	26·0768096	8·7936593	·001470588
681	463761	315821241	26·0959767	8·7979679	·001468429
682	465124	317214568	26·1151297	8·8022721	·001466276

No.	Square	Cube	Square Root	Cube Root	Reciprocal
683	466489	318611987	26·1342687	8·8065722	·001464129
684	467856	320013504	26·1533937	8·8108681	·001461988
685	469225	321419125	26·1725047	8·8151598	·001459854
686	470596	322828856	26·1916017	8·8194474	·001457726
687	471969	324242703	26·2106848	8·8237307	·001455604
688	473344	325660672	26·2297541	8·8280099	·001453488
689	474721	327082769	26·2488095	8·8322850	·001451379
690	476100	328509000	26·2678511	8·8365559	·001449275
691	477481	329939371	26·2868789	8·8408227	·001447178
692	478864	331373888	26·3058929	8·8450854	·001445087
693	480249	332812557	26·3248932	8·8493440	·001443001
694	481636	334255384	26·3438797	8·8535985	·001440922
695	483025	335702375	26·3628527	8·8578489	·001438849
696	484416	337153536	26·3818119	8·8620952	·001436782
697	485809	338608873	26·4007576	8·8663375	·001434720
698	487204	340068392	26·4196896	8·8705757	·001432665
699	488601	341532099	26·4386081	8·8748099	·001430615
700	490000	343000000	26·4575131	8·8790400	·001428571
701	491401	344472101	26·4764046	8·8832661	·001426534
702	492804	345948408	26·4952826	8·8874882	·001424501
703	494209	347428927	26·5141472	8·8917063	·001422475
704	495616	348913664	26·5329983	8·8959204	·001420455
705	497025	350402625	26·5518361	8·9001304	·001418440
706	498436	351895816	26·5706605	8·9043366	·001416431
707	499849	353393243	26·5894716	8·9085387	·001414427
708	501264	354894912	26·6082694	8·9127369	·001412429
709	502681	356400829	26·6270539	8·9169311	·001410437
710	504100	357911000	26·6458252	8·9211214	·001408451
711	505521	359425431	26·6645833	8·9253078	·001406470
712	506944	360944128	26·6833281	8·9294902	·001404494
713	508369	362467097	26·7020598	8·9336687	·001402525
714	509796	363994344	26·7207784	8·9378433	·001400560
715	511225	365525875	26·7394839	8·9420140	·001398601
716	512656	367061696	26·7581763	8·9461809	·001396648
717	514089	368601813	26·7768557	8·9503438	·001394700
718	515524	370146232	26·7955220	8·9545029	·001392758
719	516961	371694959	26·8141754	8·9586581	·001390821
720	518400	373248000	26·8328157	8·9628095	·001388889
721	519841	374805361	26·8514432	8·9669570	·001386963
722	521284	376367048	26·8700577	8·9711007	·001385042
723	522729	377933067	26·8886593	8·9752406	·001383126
724	524176	379503424	26·9072481	8·9793766	·001381215
725	525625	381078125	26·9258240	8·9835089	·001379310
726	527076	382657176	26·9443872	8·9876373	·001377410
727	528529	384240583	26·9629375	8·9917620	·001375516
728	529984	385828352	26·9814751	8·9958829	·001373626
729	531441	387420489	27·0000000	9·0000000	·001371742
730	532900	389017000	27·0185122	9·0041134	·001369863
731	534361	390617891	27·0370117	9·0082229	·001367989

No.	Square	Cube	Square Root	Cube Root	Reciprocal
732	535824	392223168	27·0554985	9·0123288	·001366120
733	537289	393832837	27·0739727	9·0164309	·001364256
734	538756	395446904	27·0924344	9·0205293	·001362398
735	540225	397065375	27·1108834	9·0246239	·001360544
736	541696	398688256	27·1293199	9·0287149	·001358696
737	543169	400315553	27·1477439	9·0328021	·001356852
738	544644	401947272	27·1661554	9·0368857	·001355014
739	546121	403583419	27·1845544	9·0409655	·001353180
740	547600	405224000	27·2029410	9·0450417	·001351351
741	549081	406869021	27·2213152	9·0491142	·001349528
742	550564	408518488	27·2396769	9·0531831	·001347709
743	552049	410172407	27·2580263	9·0572482	·001345895
744	553536	411830784	27·2763634	9·0613098	·001344086
745	555025	413493625	27·2946881	9·0653677	·001342282
746	556516	415160936	27·3130006	9·0694220	·001340483
747	558009	416832723	27·3313007	9·0734726	·001338688
748	559504	418508992	27·3495887	9·0775197	·001336898
749	561001	420189749	27·3678644	9·0815631	·001335113
750	562500	421875000	27·3861279	9·0856030	·001333333
751	564001	423564751	27·4043792	9·0896392	·001331558
752	565504	425259008	27·4226184	9·0936719	·001329787
753	567009	426957777	27·4408455	9·0977010	·001328021
754	568516	428661064	27·4590604	9·1017265	·001326260
755	570025	430368875	27·4772633	9·1057485	·001324503
756	571536	432081216	27·4954542	9·1097669	·001322751
757	573049	433798093	27·5136330	9·1137818	·001321004
758	574564	435519512	27·5317998	9·1177931	·001319261
759	576081	437245479	27·5499546	9·1218010	·001317523
760	577600	438976000	27·5680975	9·1258053	·001315789
761	579121	440711081	27·5862284	9·1298061	·001314060
762	580644	442450728	27·6043475	9·1338034	·001312336
763	582169	444194947	27·6224546	9·1377971	·001310616
764	583696	445943744	27·6405499	9·1417874	·001308901
765	585225	447697125	27·6586334	9·1457742	·001307190
766	586756	449455096	27·6767050	9·1497576	·001305483
767	588289	451217663	27·6947648	9·1537375	·001303781
768	589824	452984832	27·7128129	9·1577139	·001302083
769	591361	454756609	27·7308492	9·1616869	·001300390
770	592900	456533000	27·7488739	9·1656565	·001298701
771	594441	458314011	27·7668868	9·1696225	·001297017
772	595984	460099648	27·7848880	9·1735852	·001295337
773	597529	461889917	27·8028775	9·1775445	·001293661
774	599076	463684824	27·8208555	9·1815003	·001291990
775	600625	465484375	27·8388218	9·1854527	·001290323
776	602176	467288576	27·8567766	9·1894018	·001288660
777	603729	469097433	27·8747197	9·1933474	·001287001
778	605284	470910952	27·8926514	9·1972897	·001285347
779	606841	472729139	27·9105715	9·2012286	·001283697
780	608400	474552000	27·9284801	9·2051641	·001282051

No.	Square	Cube	Square Root	Cube Root	Reciprocal
781	609961	476379541	27·9463772	9·2090962	·001280410
782	611524	478211768	27·9642629	9·2130250	·001278772
783	613089	480048687	27·9821372	9·2169505	·001277139
784	614656	481890304	28·0000000	9·2208726	·001275510
785	616225	483736625	28·0178515	9·2247914	·001273885
786	617796	485587656	28·0356915	9·2287068	·001272265
787	619369	487443403	28·0535203	9·2326189	·001270648
788	620944	489303872	28·0713377	9·2365277	·001269036
789	622521	491169069	28·0891438	9·2404333	·001267427
790	624100	493039000	28·1069386	9·2443355	·001265823
791	625681	494913671	28·1247222	9·2482344	·001264223
792	627264	496793088	28·1424946	9·2521300	·001262626
793	628849	498677257	28·1602557	9·2560224	·001261034
794	630436	500566184	28·1780056	9·2599114	·001259446
795	632025	502459875	28·1957444	9·2637973	·001257862
796	633616	504358336	28·2134720	9·2676798	·001256281
797	635209	506261573	28·2311884	9·2715592	·001254705
798	636804	508169592	28·2488938	9·2754352	·001253133
799	638401	510082399	28·2665881	9·2793081	·001251564
800	640000	512000000	28·2842712	9·2831777	·001250000
801	641601	513922401	28·3019434	9·2870440	·001248439
802	643204	515849608	28·3196045	9·2909072	·001246883
803	644809	517781627	28·3372546	9·2947671	·001245330
804	646416	519718464	28·3548938	9·2986239	·001243781
805	648025	521660125	28·3725219	9·3024775	·001242236
806	649636	523606616	28·3901391	9·3063278	·001240695
807	651249	525557943	28·4077454	9·3101750	·001239157
808	652864	527514112	28·4253408	9·3140190	·001237624
809	654481	529475129	28·4429253	9·3178599	·001236094
810	656100	531441000	28·4604989	9·3216975	·001234568
811	657721	533411731	28·4780617	9·3255320	·001233046
812	659344	535387328	28·4956137	9·3293634	·001231527
813	660969	537367797	28·5131549	9·3331916	·001230012
814	662596	539353144	28·5306852	9·3370167	·001228501
815	664225	541343375	28·5482048	9·3408386	·001226994
816	665856	543338496	28·5657137	9·3446575	·001225490
817	667489	545338513	28·5832119	9·3484731	·001223990
818	669124	547343432	28·6006993	9·3522857	·001222494
819	670761	549353259	28·6181760	9·3560952	·001221001
820	672400	551368000	28·6356421	9·3599016	·001219512
821	674041	553387661	28·6530976	9·3637049	·001218027
822	675684	555412248	28·6705424	9·3675051	·001216545
823	677329	557441767	28·6879766	9·3713022	·001215067
824	678976	559476224	28·7054002	9·3750963	·001213592
825	680625	561515625	28·7228132	9·3788873	·001212121
826	682276	563559976	28·7402157	9·3826752	·001210654
827	683929	565609283	28·7576077	9·3864600	·001209190
828	685584	567663552	28·7749891	9·3902419	·001207729
829	687241	569722789	28·7923601	9·3940206	·001206272

No.	Square	Cube	Square Root	Cube Root	Reciprocal
830	688900	571787000	28·8097206	9·3977964	·001204819
831	690561	573856191	28·8270706	9·4015691	·001203369
832	692224	575930368	28·8444102	9·4053387	·001201923
833	693889	578009537	28·8617394	9·4091054	·001200480
834	695556	580093704	28·8790582	9·4128690	·001199041
835	697225	582182875	28·8963666	9·4166297	·001197605
836	698896	584277056	28·9136646	9·4203873	·001196172
837	700569	586376253	28·9309523	9·4241420	·001194743
838	702244	588480472	28·9482297	9·4278936	·001193317
839	703921	590589719	28·9654967	9·4316423	·001191895
840	705600	592704000	28·9827535	9·4353880	·001190476
841	707281	594823321	29·0000000	9·4391307	·001189061
842	708964	596947688	29·0172363	9·4428704	·001187648
843	710649	599077107	29·0344623	9·4466072	·001186240
844	712336	601211584	29·0516781	9·4503410	·001184834
845	714025	603351125	29·0688837	9·4540719	·001183432
846	715716	605495736	29·0860791	9·4577999	·001182033
847	717409	607645423	29·1032644	9·4615249	·001180638
848	719104	609800192	29·1204396	9·4652470	·001179245
849	720801	611960049	29·1376046	9·4689661	·001177856
850	722500	614125000	29·1547595	9·4726824	·001176471
851	724201	616295051	29·1719043	9·4763957	·001175088
852	725904	618470208	29·1890390	9·4801061	·001173709
853	727609	620650477	29·2061637	9·4838136	·001172333
854	729316	622835864	29·2232784	9·4875182	·001170960
855	731025	625026375	29·2403830	9·4912200	·001169591
856	732736	627222016	29·2574777	9·4949188	·001168224
857	734449	629422793	29·2745623	9·4986147	·001166861
858	736164	631628712	29·2916370	9·5023078	·001165501
859	737881	633839779	29·3087018	9·5059980	·001164144
860	739600	636056000	29·3257566	9·5096854	·001162791
861	741321	638277381	29·3428015	9·5133699	·001161440
862	743044	640503928	29·3598365	9·5170515	·001160093
863	744769	642735647	29·3768616	9·5207303	·001158749
864	746496	644972544	29·3938769	9·5244063	·001157407
865	748225	647214625	29·4108823	9·5280794	·001156069
866	749956	649461896	29·4278779	9·5317497	·001154734
867	751689	651714363	29·4448637	9·5354172	·001153403
868	753424	653972032	29·4618397	9·5390818	·001152074
869	755161	656234909	29·4788059	9·5427437	·001150748
870	756900	658503000	29·4957624	9·5464027	·001149425
871	758641	660776311	29·5127091	9·5500589	·001148106
872	760384	663054848	29·5296461	9·5537123	·001146789
873	762129	665338617	29·5465734	9·5573630	·001145475
874	763876	667627624	29·5634910	9·5610108	·001144165
875	765625	669921875	29·5803989	9·5646559	·001142857
876	767376	672221376	29·5972972	9·5682982	·001141553
877	769129	674526133	29·6141858	9·5719377	·001140251
878	770884	676836152	29·6310648	9·5755745	·001138952

No.	Square	Cube	Square Root	Cube Root	Reciprocal
879	772641	679151439	29·6479342	9·5792085	·001137656
880	774400	681472000	29·6647939	9·5828397	·001136364
881	776161	683797841	29·6816442	9·5864682	·001135074
882	777924	686128968	29·6984848	9·5900939	·001133787
883	779689	688465387	29·7153159	9·5937169	·001132503
884	781456	690807104	29·7321375	9·5973373	·001131222
885	783225	693154125	29·7489496	9·6009548	·001129944
886	784996	695506456	29·7657521	9·6045696	·001128668
887	786769	697864103	29·7825452	9·6081817	·001127396
888	788544	700227072	29·7993289	9·6117911	·001126126
889	790321	702595369	29·8161030	9·6153977	·001124859
890	792100	704969000	29·8328678	9·6190017	·001123596
891	793881	707347971	29·8496231	9·6226030	·001122334
892	795664	709732288	29·8663690	9·6262016	·001121076
893	797449	712121957	29·8831056	9·6297975	·001119821
894	799236	714516984	29·8998328	9·6333907	·001118568
895	801025	716917375	29·9165506	9·6369812	·001117318
896	802816	719323136	29·9332591	9·6405690	·001116071
897	804609	721734273	29·9499583	9·6441542	·001114827
898	806404	724150792	29·9666481	9·6477367	·001113586
899	808201	726572699	29·9833287	9·6513166	·001112347
900	810000	729000000	30·0000000	9·6548938	·001111111
901	811801	731432701	30·0166620	9·6584684	·001109878
902	813604	733870808	30·0333148	9·6620403	·001108647
903	815409	736314327	30·0499584	9·6656096	·001107420
904	817216	738763264	30·0665928	9·6691762	·001106195
905	819025	741217625	30·0832179	9·6727403	·001104972
906	820836	743677416	30·0998339	9·6763017	·001103753
907	822649	746142643	30·1164407	9·6798604	·001102536
908	824464	748613312	30·1330383	9·6834166	·001101322
909	826281	751089429	30·1496269	9·6869701	·001100110
910	828100	753571000	30·1662063	9·6905211	·001098901
911	829921	756058031	30·1827765	9·6940694	·001097695
912	831744	758550528	30·1993377	9·6976151	·001096491
913	833569	761048497	30·2158899	9·7011583	·001095290
914	835396	763551944	30·2324329	9·7046989	·001094092
915	837225	766060875	30·2489669	9·7082369	·001092896
916	839056	768575296	30·2654919	9·7117723	·001091703
917	840889	771095213	30·2820079	9·7153051	·001090513
918	842724	773620632	30·2985148	9·7188354	·001089325
919	844561	776151559	30·3150128	9·7223631	·001088139
920	846400	778688000	30·3315018	9·7258883	·001086957
921	848241	781229961	30·3479818	9·7294109	·001085776
922	850084	783777448	30·3644529	9·7329309	·001084599
923	851929	786330467	30·3809151	9·7364484	·001083424
924	853776	788889024	30·3973683	9·7399634	·001082251
925	855625	791453125	30·4138127	9·7434758	·001081081
926	857476	794022776	30·4302481	9·7469857	·001079914
927	859329	796597983	30·4466747	9·7504930	·001078749

No.	Square	Cube	Square Root	Cube Root	Reciprocal
928	861184	799178752	30·4630924	9·7539979	·001077586
929	863041	801765089	30·4795013	9·7575002	·001076426
930	864900	804357000	30·4959014	9·7610001	·001075269
931	866761	806954491	30·5122926	9·7644974	·001074114
932	868624	809557568	30·5286750	9·7679922	·001072961
933	870489	812166237	30·5450487	9·7714845	·001071811
934	872356	814780504	30·5614136	9·7749743	·001070664
935	874225	817400375	30·5777697	9·7784616	·001069519
936	876096	820025856	30·5941171	9·7819466	·001068376
937	877969	822656953	30·6104557	9·7854288	·001067236
938	879844	825293672	30·6267857	9·7889087	·001066098
939	881721	827936019	30·6431069	9·7923861	·001064963
940	883600	830584000	30·6594194	9·7958611	·001063830
941	885481	833237621	30·6757233	9·7993336	·001062699
942	887364	835896888	30·6920185	9·8028036	·001061571
943	889249	838561807	30·7083051	9·8062711	·001060445
944	891136	841232384	30·7245830	9·8097362	·001059322
945	893025	843908625	30·7408523	9·8131989	·001058201
946	894916	846590536	30·7571130	9·8166591	·001057082
947	896809	849278123	30·7733651	9·8201169	·001055966
948	898704	851971392	30·7896086	9·8235723	·001054852
949	900601	854670349	30·8058436	9·8270252	·001053741
950	902500	857375000	30·8220700	9·8304757	·001052632
951	904401	860085351	30·8382879	9·8339238	·001051525
952	906304	862801408	30·8544972	9·8373695	·001050420
953	908209	865523177	30·8706981	9·8408127	·001049318
954	910116	868250664	30·8868904	9·8442536	·001048218
955	912025	870983875	30·9030743	9·8476920	·001047120
956	913936	873722816	30·9192497	9·8511280	·001046025
957	915849	876467493	30·9354166	9·8545617	·001044932
958	917764	879217912	30·9515751	9·8579929	·001043841
959	919681	881974079	30·9677251	9·8614218	·001042753
960	921600	884736000	30·9838668	9·8648483	·001041667
961	923521	887503681	31·0000000	9·8682724	·001040583
962	925444	890277128	31·0161248	9·8716941	·001039501
963	927369	893056347	31·0322413	9·8751135	·001038422
964	929296	895841344	31·0483494	9·8785305	·001037344
965	931225	898632125	31·0644491	9·8819451	·001036269
966	933156	901428696	31·0805405	9·8853574	·001035197
967	935089	904231063	31·0966236	9·8887673	·001034126
968	937024	907039232	31·1126984	9·8921749	·001033058
969	938961	909853209	31·1287648	9·8955801	·001031992
970	940900	912673000	31·1448230	9·8989830	·001030928
971	942841	915498611	31·1608729	9·9023835	·001029866
972	944784	918330048	31·1769145	9·9057817	·001028807
973	946729	921167317	31·1929479	9·9091776	·001027749
974	948676	924010424	31·2089731	9·9125712	·001026694
975	950625	926859375	31·2249900	9·9159624	·001025641
976	952576	929714176	31·2409987	9·9193513	·001024590

No.	Square	Cube	Square Root	Cube Root	Reciprocal
977	954529	932574833	31·2569992	9·9227379	·001023541
978	956484	935441352	31·2729915	9·9261222	·001022495
979	958441	938313739	31·2889757	9·9295042	·001021450
980	960400	941192000	31·3049517	9·9328839	·001020408
981	962361	944076141	31·3209195	9·9362613	·001019368
982	964324	946966168	31·3368792	9·9396363	·001018330
983	966289	949862087	31·3528308	9·9430092	·001017294
984	968256	952763904	31·3687743	9·9463797	·001016260
985	970225	955671625	31·3847097	9·9497479	·001015228
986	972196	958585256	31·4006369	9·9531138	·001014199
987	974169	961504803	31·4165561	9·9564775	·001013171
988	976144	964430272	31·4324673	9·9598389	·001012146
989	978121	967361669	31·4483704	9·9631981	·001011122
990	980100	970299000	31·4642654	9·9665549	·001010101
991	982081	973242271	31·4801525	9·9699095	·001009082
992	984064	976191488	31·4960315	9·9732619	·001008065
993	986049	979146657	31·5119025	9·9766120	·001007049
994	988036	982107784	31·5277655	9·9799599	·001006036
995	990025	985074875	31·5436206	9·9833055	·001005025
996	992016	988047936	31·5594677	9·9866488	·001004016
997	994009	991026973	31·5753068	9·9899900	·001003009
998	996004	994011992	31·5911380	9·9933289	·001002004
999	998001	997002999	31·6069613	9·9966656	·001001001
1000	1000000	1000000000	31·6227766	10·0000000	·0010000000
1001	1002001	1003003001	31·6385840	10·0033322	·0009990010
1002	1004004	1006012008	31·6543836	10·0066622	·0009980040
1003	1006009	1009027027	31·6701752	10·0099899	·0009970090
1004	1008016	1012048064	31·6859590	10·0133155	·0009960159
1005	1010025	1015075125	31·7017349	10·0166389	·0009950249
1006	1012036	1018108216	31·7175030	10·0199601	·0009940358
1007	1014049	1021147343	31·7332633	10·0232791	·0009930487
1008	1016064	1024192512	31·7490157	10·0265958	·0009920635
1009	1018081	1027243729	31·7647603	10·0299104	·0009910803
1010	1020100	1030301000	31·7804972	10·0332228	·0009900990
1011	1022121	1033364331	31·7962262	10·0365330	·0009891197
1012	1024144	1036433728	31·8119474	10·0398410	·0009881423
1013	1026169	1039509197	31·8276609	10·0431469	·0009871668
1014	1028196	1042590744	31·8433666	10·0464506	·0009861933
1015	1030225	1045678375	31·8590646	10·0497521	·0009852217
1016	1032256	1048772096	31·8747549	10·0530514	·0009842520
1017	1034289	1051871913	31·8904374	10·0563485	·0009832842
1018	1036324	1054977832	31·9061123	10·0596435	·0009823183
1019	1038361	1058089859	31·9217794	10·0629364	·0009813543
1020	1040400	1061208000	31·9374388	10·0662271	·0009803922
1021	1042441	1064332261	31·9530906	10·0695156	·0009794319
1022	1044484	1067462648	31·9687347	10·0728020	·0009784736
1023	1046529	1070599167	31·9843712	10·0760863	·0009775171
1024	1048576	1073741824	32·0000000	10·0793684	·0009765625
1025	1050625	1076890625	32·0156212	10·0826484	·0009756098

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1026	1052676	1080045576	32·0312348	10·0859262	·0009746589
1027	1054729	1083206683	32·0468407	10·0892019	·0009737098
1028	1056784	1086373952	32·0624391	10·0924755	·0009727626
1029	1058841	1089547389	32·0780298	10·0957469	·0009718173
1030	1060900	1092727000	32·0936131	10·0990163	·0009708738
1031	1062961	1095912791	32·1091887	10·1022835	·0009699321
1032	1065024	1099104768	32·1247568	10·1055487	·0009689922
1033	1067089	1102302937	32·1403173	10·1088117	·0009680542
1034	1069156	1105507304	32·1558704	10·1120726	·0009671180
1035	1071225	1108717875	32·1714159	10·1153314	·0009661836
1036	1073296	1111934656	32·1869539	10·1185882	·0009652510
1037	1075369	1115157653	32·2024844	10·1218428	·0009643202
1038	1077444	1118386872	32·2180074	10·1250953	·0009633911
1039	1079521	1121622319	32·2335229	10·1283457	·0009624639
1040	1081600	1124864000	32·2490310	10·1315941	·0009615385
1041	1083681	1128111921	32·2645316	10·1348403	·0009606148
1042	1085764	1131366088	32·2800248	10·1380845	·0009596929
1043	1087849	1134626507	32·2955105	10·1413266	·0009587728
1044	1089936	1137893184	32·3109888	10·1445667	·0009578544
1045	1092025	1141166125	32·3264598	10·1478047	·0009569378
1046	1094116	1144445336	32·3419233	10·1510406	·0009560229
1047	1096209	1147730823	32·3573794	10·1542744	·0009551098
1048	1098304	1151022592	32·3728281	10·1575062	·0009541985
1049	1100401	1154320649	32·3882695	10·1607359	·0009532888
1050	1102500	1157625000	32·4037035	10·1639636	·0009523810
1051	1104601	1160935651	32·4191301	10·1671893	·0009514748
1052	1106704	1164252608	32·4345495	10·1704129	·0009505703
1053	1108809	1167575877	32·4499615	10·1736344	·0009496676
1054	1110916	1170905464	32·4653662	10·1768539	·0009487666
1055	1113025	1174241375	32·4807635	10·1800714	·0009478673
1056	1115136	1177583616	32·4961536	10·1832868	·0009469697
1057	1117249	1180932193	32·5115364	10·1865002	·0009460738
1058	1119364	1184287112	32·5269119	10·1897116	·0009451796
1059	1121481	1187648379	32·5422802	10·1929209	·0009442871
1060	1123600	1191016000	32·5576412	10·1961283	·0009433962
1061	1125721	1194389981	32·5729949	10·1993336	·0009425071
1062	1127844	1197770328	32·5883415	10·2025369	·0009416196
1063	1129969	1201157047	32·6036807	10·2057382	·0009407338
1064	1132096	1204550144	32·6190129	10·2089375	·0009398496
1065	1134225	1207949625	32·6343377	10·2121347	·0009389671
1066	1136356	1211355496	32·6496554	10·2153300	·0009380863
1067	1138489	1214767763	32·6649659	10·2185233	·0009372071
1068	1140624	1218186432	32·6802693	10·2217146	·0009363296
1069	1142761	1221611509	32·6955654	10·2249039	·0009354537
1070	1144900	1225043000	32·7108544	10·2280912	·0009345794
1071	1147041	1228480911	32·7261363	10·2312766	·0009337068
1072	1149184	1231925248	32·7414111	10·2344599	·0000328358
1073	1151329	1235376017	32·7566787	10·2376413	·0009319664
1074	1153476	1238833224	32·7719392	10·2408207	·0009310987

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1075	1155625	1242296875	32·7871926	10·2439981	·0009302326
1076	1157776	1245766976	32·8024389	10·2471735	·0009293680
1077	1159929	1249243533	32·8176782	10·2503470	·0009285051
1078	1162084	1252726552	32·8329103	10·2535186	·0009276438
1079	1164241	1256216039	32·8481354	10·2566881	·0009267841
1080	1166400	1259712000	32·8633535	10·2598557	·0009259259
1081	1168561	1263214441	32·8785644	10·2630213	·0009250694
1082	1170724	1266723368	32·8937684	10·2661850	·0009242144
1083	1172889	1270238787	32·9089653	10·2693467	·0009233610
1084	1175056	1273760704	32·9241553	10·2725065	·0009225092
1085	1177225	1277289125	32·9393382	10·2756644	·0009216590
1086	1179396	1280824056	32·9545141	10·2788203	·0009208103
1087	1181569	1284365503	32·9696830	10·2819743	·0009199632
1088	1183744	1287913472	32·9848450	10·2851264	·0009191176
1089	1185921	1291467969	33·0000000	10·2882765	·0009182736
1090	1188100	1295029000	33·0151480	10·2914247	·0009174312
1091	1190281	1298596571	33·0302891	10·2945709	·0009165903
1092	1192464	1302170688	33·0454233	10·2977153	·0009157509
1093	1194649	1305751357	33·0605505	10·3008577	·0009149131
1094	1196836	1309338584	33·0756708	10·3039982	·0009140768
1095	1199025	1312932375	33·0907842	10·3071368	·0009132420
1096	1201216	1316532736	33·1058907	10·3102735	·0009124088
1097	1203409	1320139673	33·1209903	10·3134083	·0009115770
1098	1205604	1323753192	33·1360830	10·3165411	·0009107468
1099	1207801	1327373299	33·1511689	10·3196721	·0009099181
1100	1210000	1331000000	33·1662479	10·3228012	·0009090909
1101	1212201	1334633301	33·1813200	10·3259284	·0009082652
1102	1214404	1338273208	33·1963853	10·3290537	·0009074410
1103	1216609	1341919727	33·2114438	10·3321770	·0009066183
1104	1218816	1345572864	33·2264955	10·3352985	·0009057971
1105	1221025	1349232625	33·2415403	10·3384181	·0009049774
1106	1223236	1352899016	33·2565783	10·3415358	·0009041591
1107	1225449	1356572043	33·2716095	10·3446517	·0009033424
1108	1227664	1360251712	33·2866339	10·3477657	·0009025271
1109	1229881	1363938029	33·3016516	10·3508778	·0009017133
1110	1232100	1367631000	33·3166625	10·3539880	·0009009009
1111	1234321	1371330631	33·3316666	10·3570964	·0009000900
1112	1236544	1375036928	33·3466640	10·3602029	·0008992806
1113	1238769	1378749897	33·3616546	10·3633076	·0008984726
1114	1240996	1382469544	33·3766385	10·3664103	·0008976661
1115	1243225	1386195875	33·3916157	10·3695113	·0008968610
1116	1245456	1389928896	33·4065862	10·3726103	·0008960573
1117	1247689	1393668613	33·4215499	10·3757076	·0008952551
1118	1249924	1397415032	33·4365070	10·3788030	·0008944544
1119	1252161	1401168159	33·4514573	10·3818965	·0008936550
1120	1254400	1404928000	33·4664011	10·3849882	·0008928571
1121	1256641	1408694561	33·4813381	10·3880781	·0008920607
1122	1258884	1412467848	33·4962684	10·3911661	·0008912656
1123	1261129	1416247867	33·5111921	10·3942523	·0008904720

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1124	1263376	1420034624	33·5261092	10·3973366	·0008896797
1125	1265625	1423828125	33·5410196	10·4004192	·0008888889
1126	1267876	1427628376	33·5559234	10·4034999	·0008880995
1127	1270129	1431435383	33·5708206	10·4065787	·0008873114
1128	1272384	1435249152	33·5857112	10·4096557	·0008865248
1129	1274641	1439069689	33·6005952	10·4127310	·0008857396
1130	1276900	1442897000	33·6154726	10·4158044	·0008849558
1131	1279161	1446731091	33·6303434	10·4188760	·0008841733
1132	1281424	1450571968	33·6452077	10·4219458	·0008833922
1133	1283689	1454419637	33·6600653	10·4250138	·0008826125
1134	1285956	1458274104	33·6749165	10·4280800	·0008818342
1135	1288225	1462135375	33·6897610	10·4311443	·0008810573
1136	1290496	1466003456	33·7045991	10·4342069	·0008802817
1137	1292769	1469878353	33·7194306	10·4372677	·0008795075
1138	1295044	1473760072	33·7342556	10·4403267	·0008787346
1139	1297321	1477648619	33·7490741	10·4433839	·0008779631
1140	1299600	1481544000	33·7638860	10·4464393	·0008771930
1141	1301881	1485446221	33·7786915	10·4494929	·0008764242
1142	1304164	1489355288	33·7934905	10·4525448	·0008756567
1143	1306449	1493271207	33·8082830	10·4555948	·0008748906
1144	1308736	1497193984	33·8230691	10·4586431	·0008741259
1145	1311025	1501123625	33·8378486	10·4616896	·0008733624
1146	1313316	1505060136	33·8526218	10·4647343	·0008726003
1147	1315609	1509003523	33·8673884	10·4677773	·0008718396
1148	1317904	1512953792	33·8821487	10·4708185	·0008710801
1149	1320201	1516910949	33·8969025	10·4738579	·0008703220
1150	1322500	1520875000	33·9116499	10·4768955	·0008695652
1151	1324801	1524845951	33·9263909	10·4799314	·0008688097
1152	1327104	1528823808	33·9411255	10·4829656	·0008680556
1153	1329409	1532808577	33·9558537	10·4859980	·0008673027
1154	1331716	1536800264	33·9705755	10·4890286	·0008665511
1155	1334025	1540798875	33·9852910	10·4920575	·0008658009
1156	1336336	1544804416	34·0000000	10·4950847	·0008650519
1157	1338649	1548816893	34·0147027	10·4981101	·0008643042
1158	1340964	1552836312	34·0293990	10·5011337	·0008635579
1159	1343281	1556862679	34·0440890	10·5041556	·0008628128
1160	1345600	1560896000	34·0587727	10·5071757	·0008620690
1161	1347921	1564936281	34·0734501	10·5101942	·0008613264
1162	1350244	1568983528	34·0881211	10·5132109	·0008605852
1163	1352569	1573037747	34·1027858	10·5162259	·0008598452
1164	1354896	1577098944	34·1174442	10·5192391	·0008591065
1165	1357225	1581167125	34·1320963	10·5222506	·0008583691
1166	1359556	1585242296	34·1467422	10·5252604	·0008576329
1167	1361889	1589324463	34·1613817	10·5282685	·0008568980
1168	1364224	1593413632	34·1760150	10·5312749	·0008561644
1169	1366561	1597509809	34·1906420	10·5342795	·0008554320
1170	1368900	1601613000	34·2052627	10·5372825	·0008547009
1171	1371241	1605723211	34·2198773	10·5402837	·0008539710
1172	1373584	1609840448	34·2344855	10·5432832	·0008532423

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1173	1375929	1613964717	34·2490875	10·5462810	·0008525149
1174	1378276	1618096024	34·2636834	10·5492771	·0008517888
1175	1380625	1622234375	34·2782730	10·5522715	·0008510638
1176	1382976	1626379776	34·2928564	10·5552642	·0008503401
1177	1385329	1630532233	34·3074336	10·5582552	·0008496177
1178	1387684	1634691752	34·3220046	10·5612445	·0008488964
1179	1390041	1638858339	34·3365694	10·5642322	·0008481764
1180	1392400	1643032000	34·3511281	10·5672181	·0008474576
1181	1394761	1647212741	34·3656805	10·5702024	·0008467401
1182	1397124	1651400568	34·3802268	10·5731849	·0008460237
1183	1399489	1655595487	34·3947670	10·5761658	·0008453085
1184	1401856	1659797504	34·4093011	10·5791449	·0008445946
1185	1404225	1664006625	34·4238289	10·5821225	·0008438819
1186	1406596	1668222856	34·4383507	10·5850983	·0008431703
1187	1408969	1672446203	34·4528663	10·5880725	·0008424600
1188	1411344	1676676672	34·4673759	10·5910450	·0008417508
1189	1413721	1680914269	34·4818793	10·5940158	·0008410429
1190	1416100	1685159000	34·4963766	10·5969850	·0008403361
1191	1418481	1689410871	34·5108678	10·5999525	·0008396306
1192	1420864	1693669888	34·5253530	10·6029184	·0008389262
1193	1423249	1697936057	34·5398321	10·6058826	·0008382230
1194	1425636	1702209384	34·5543051	10·6088451	·0008375209
1195	1428025	1706489875	34·5687720	10·6118060	·0008368201
1196	1430416	1710777536	34·5832329	10·6147652	·0008361204
1197	1432809	1715072373	34·5976879	10·6177228	·0008354219
1198	1435204	1719374392	34·6121366	10·6206788	·0008347245
1199	1437601	1723683599	34·6265794	10·6236331	·0008340284
1200	1440000	1728000000	34·6410162	10·6265857	·0008333333
1201	1442401	1732323601	34·6554469	10·6295367	·0008326395
1202	1444804	1736654408	34·6698716	10·6324860	·0008319468
1203	1447209	1740992427	34·6842904	10·6354338	·0008312552
1204	1449616	1745337664	34·6987031	10·6383799	·0008305648
1205	1452025	1749690125	34·7131099	10·6413244	·0008298755
1206	1454436	1754049816	34·7275107	10·6442672	·0008291874
1207	1456849	1758416743	34·7419055	10·6472085	·0008285004
1208	1459264	1762790912	34·7562944	10·6501480	·0008278146
1209	1461681	1767172329	34·7706773	10·6530860	·0008271299
1210	1464100	1771561000	34·7850543	10·6560223	·0008264463
1211	1466521	1775956931	34·7994253	10·6589570	·0008257638
1212	1468944	1780360128	34·8137904	10·6618902	·0008250825
1213	1471369	1784770597	34·8281495	10·6648217	·0008244023
1214	1473796	1789188344	34·8425028	10·6677516	·0008237232
1215	1476225	1793613375	34·8568501	10·6706799	·0008230453
1216	1478656	1798045696	34·8711915	10·6736066	·0008223684
1217	1481089	1802485313	34·8855271	10·6765317	·0008216927
1218	1483524	1806932232	34·8998567	10·6794552	·0008210181
1219	1485961	1811386459	34·9141805	10·6823771	·0008203445
1220	1488400	1815848000	34·9284984	10·6852973	·0008196721
1221	1490841	1820316861	34·9428104	10·6882160	·0008190008

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1222	1493284	1824793048	34·9571166	10·6911331	·0008183306
1223	1495729	1829276567	34·9714169	10·6940486	·0008176615
1224	1498176	1833767424	34·9857114	10·6969625	·0008169935
1225	1500625	1838265625	35·0000000	10·6998748	·0008163265
1226	1503076	1842771176	35·0142828	10·7027855	·0008156607
1227	1505529	1847284083	35·0285598	10·7056947	·0008149959
1228	1507984	1851804352	35·0428309	10·7086023	·0008143322
1229	1510441	1856331989	35·0570963	10·7115083	·0008136696
1230	1512900	1860867000	35·0713558	10·7144127	·0008130081
1231	1515361	1865409391	35·0856096	10·7173155	·0008123477
1232	1517824	1869959168	35·0998575	10·7202168	·0008116883
1233	1520289	1874516337	35·1140997	10·7231165	·0008110300
1234	1522756	1879080904	35·1283361	10·7260146	·0008103728
1235	1525225	1883652875	35·1425668	10·7289112	·0008097166
1236	1527696	1888232256	35·1567917	10·7318062	·0008090615
1237	1530169	1892819053	35·1710108	10·7346997	·0008084074
1238	1532644	1897413272	35·1852242	10·7375916	·0008077544
1239	1535121	1902014919	35·1994318	10·7404819	·0008071025
1240	1537600	1906624000	35·2136337	10·7433707	·0008064516
1241	1540081	1911240521	35·2278299	10·7462579	·0008058018
1242	1542564	1915864488	35·2420204	10·7491436	·0008051530
1243	1545049	1920495907	35·2562051	10·7520277	·0008045052
1244	1547536	1925134784	35·2703842	10·8549103	·0008038585
1245	1550025	1929781125	35·2845575	10·7577913	·0008032129
1246	1552516	1934434936	35·2987252	10·7606708	·0008025682
1247	1555009	1939096223	35·3128872	10·7635488	·0008019246
1248	1557504	1943764992	35·3270435	10·7664252	·0008012821
1249	1560001	1948441249	35·3411941	10·7693001	·0008006405
1250	1562500	1953125000	35·3553391	10·7721735	·0008000000
1251	1565001	1957816251	35·3694784	10·7750453	·0007993605
1252	1567504	1962515008	35·3836120	10·7779156	·0007987220
1253	1570009	1967221277	35·3977400	10·7807843	·0007980846
1254	1572516	1971935064	35·4118624	10·7836516	·0007974482
1255	1575025	1976656375	35·4259792	10·7865173	·0007968127
1256	1577536	1981385216	35·4400903	10·7893815	·0007961783
1257	1580049	1986121593	35·4541958	10·7922441	·0007955449
1258	1582564	1990865512	35·4682957	10·7951053	·0007949126
1259	1585081	1995616979	35·4823900	10·7979649	·0007942812
1260	1587600	2000376000	35·4964787	10·8008230	·0007936508
1261	1590121	2005142581	35·5105618	10·8036797	·0007930214
1262	1592644	2009916728	35·5246393	10·8065348	·0007923930
1263	1595169	2014698447	35·5387113	10·8093884	·0007917656
1264	1597696	2019487744	35·5527777	10·8122404	·0007911392
1265	1600225	2024284625	35·5668385	10·8150909	·0007905138
1266	1602756	2029089096	35·5808937	10·8179400	·0007898894
1267	1605289	2033901163	35·5949434	10·8207876	·0007892660
1268	1607824	2038720832	35·6089876	10·8236336	·0007886435
1269	1610361	2043548109	35·6230262	10·8264782	·0007880221
1270	1612900	2048383000	35·6370593	10·8293213	·0007874016

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1271	1615441	2053225511	35·6510869	10·8321629	·0007867821
1272	1617984	2058075648	35·6651090	10·8350030	·0007861635
1273	1620529	2062933417	35·6791255	10·8378416	·0007855460
1274	1623076	2067798824	35·6931366	10·8406788	·0007849294
1275	1625625	2072671875	35·7071421	10·8435144	·0007843137
1276	1628176	2077552576	35·7211422	10·8463485	·0007836991
1277	1630729	2082440933	35·7351367	10·8491812	·0007830854
1278	1633284	2087336952	35·7491258	10·8520125	·0007824726
1279	1635841	2092240639	35·7631095	10·8548422	·0007818608
1280	1638400	2097152000	35·7770876	10·8576704	·0007812500
1281	1640961	2102071041	35·7910603	10·8604972	·0007806401
1282	1643524	2106997768	35·8050276	10·8633225	·0007800312
1283	1646089	2111932187	35·8189894	10·8661464	·0007794232
1284	1648656	2116874304	35·8329457	10·8689687	·0007788162
1285	1651225	2121824125	35·8468966	10·8717897	·0007782101
1286	1653796	2126781656	35·8608421	10·8746091	·0007776050
1287	1656369	2131746903	35·8747822	10·8774271	·0007770008
1288	1658944	2136719872	35·8887169	10·8802436	·0007763975
1289	1661521	2141700569	35·9026461	10·8830587	·0007757952
1290	1664100	2146689000	35·9165699	10·8858723	·0007751938
1291	1666681	2151685171	35·9304884	10·8886845	·0007745933
1292	1669264	2156689088	35·9444015	10·8914952	·0007739938
1293	1671849	2161700757	35·9583092	10·8943044	·0007733952
1294	1674436	2166720184	33·9722115	10·8971123	·0007727975
1295	1677025	2171747375	35·9861084	10·8999186	·0007722008
1296	1679616	2176782336	36·0000000	10·9027235	·0007716049
1297	1682209	2181825073	36·0138862	10·9055269	·0007710100
1298	1684804	2186875592	36·0277671	10·9083290	·0007704160
1299	1687401	2191933899	36·0416426	10·9111296	·0007698229
1300	1690000	2197000000	36·0555128	10·9139287	·0007692308
1301	1692601	2202073901	36·0693776	10·9167265	·0007686395
1302	1695204	2207155608	36·0832371	10·9195228	·0007680492
1303	1697809	2212245127	36·0970913	10·9223177	·0007674597
1304	1700416	2217342464	36·1109402	10·9251111	·0007668712
1305	1703025	2222447625	36·1247837	10·9279031	·0007662835
1306	1705636	2227560616	36·1386220	10·9306937	·0007656968
1307	1708249	2232681443	36·1524550	10·9334829	·0007651109
1308	1710864	2237810112	36·1662826	10·9362706	·0007645260
1309	1713481	2242946629	36·1801050	10·9390569	·0007639419
1310	1716100	2248091000	36·1939221	10·9418418	·0007633588
1311	1718721	2253243231	36·2077340	10·9446253	·0007627765
1312	1721344	2258403328	36·2215406	10·9474074	·0007621951
1313	1723969	2263571297	36·2353419	10·9501880	·0007616146
1314	1726596	2268747144	36·2491379	10·9529673	·0007610350
1315	1729225	2273930875	36·2629287	10·9557451	·0007604563
1316	1731856	2279122496	36·2767143	10·9585215	·0007598784
1317	1734489	2284322013	36·2904946	10·9612965	·0007593014
1318	1737124	2289529432	36·3042697	10·9640701	·0007587253
1319	1739761	2294744759	36·3180396	10·9668423	·0007581501

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1320	1742400	2299968000	36·3318042	10·9696131	·0007575758
1321	1745041	2305199161	36·3455637	10·9723825	·0007570023
1322	1747684	2310438248	36·3593179	10·9751505	·0007564297
1323	1750329	2315685267	36·3730670	10·9779171	·0007558579
1324	1752976	2320940224	36·3868108	10·9806823	·0007552870
1325	1755625	2326203125	36·4005494	10·9834462	·0007547170
1326	1758276	2331473976	36·4142829	10·9862086	·0007541478
1327	1760929	2336752783	36·4280112	10·9889696	·0007535795
1328	1763584	2342039552	36·4417343	10·9917293	·0007530120
1329	1766241	2347334289	36·4554523	10·9944876	·0007524454
1330	1768900	2352637000	36·4691650	10·9972445	·0007518797
1331	1771561	2357947691	36·4828727	11·0000000	·0007513148
1332	1774224	2363266368	36·4965752	11·0027541	·0007507508
1333	1776889	2368593037	36·5102725	11·0055069	·0007501875
1334	1779556	2373927704	36·5239647	11·0082583	·0007496252
1335	1782225	2379270375	36·5376518	11·0110082	·0007490637
1336	1784896	2384621056	36·5513338	11·0137569	·0007485030
1337	1787569	2389979753	36·5650106	11·0165041	·0007479432
1338	1790244	2395346472	36·5786823	11·0192500	·0007473842
1339	1792921	2400721219	36·5923489	11·0219945	·0007468260
1340	1795600	2406104000	36·6060104	11·0247377	·0007462687
1341	1798281	2411494821	36·6196668	11·0274795	·0007457122
1342	1800964	2416893688	36·6333181	11·0302199	·0007451565
1343	1803649	2422300607	36·6469644	11·0329590	·0007446016
1344	1806336	2427715584	36·6606056	11·0356967	·0007440476
1345	1809025	2433138625	36·6742416	11·0384330	·0007434944
1346	1811716	2438569736	36·6878726	11·0411680	·0007429421
1347	1814409	2444008923	36·7014986	11·0439017	·0007423905
1348	1817104	2449456192	36·7151195	11·0466339	·0007418398
1349	1819801	2454911549	36·7287353	11·0493649	·0007412898
1350	1822500	2460375000	36·7423461	11·0520945	·0007407407
1351	1825201	2465846551	36·7559519	11·0548227	·0007401924
1352	1827904	2471326208	36·7695526	11·0575497	·0007396450
1353	1830609	2476813977	36·7831483	11·0602752	·0007390983
1354	1833316	2482309864	36·7967390	11·0629994	·0007385524
1355	1836025	2487813875	36·8103246	11·0657222	·0007380074
1356	1838736	2493326016	36·8239053	11·0684437	·0007374631
1357	1841449	2498846293	36·8374809	11·0711639	·0007369197
1358	1844164	2504374712	36·8510515	11·0738828	·0007363770
1359	1846881	2509911279	36·8646172	11·0766003	·0007358352
1360	1849600	2515456000	36·8781778	11·0793165	·0007352941
1361	1852321	2521008881	36·8917335	11·0820314	·0007347539
1362	1855044	2526569928	36·9052842	11·0847449	·0007342144
1363	1857769	2532139147	36·9188299	11·0874571	·0007336757
1364	1860496	2537716544	36·9323706	11·0901679	·0007331378
1365	1863225	2543302125	36·9459064	11·0928775	·0007326007
1366	1865956	2548895896	36·9594372	11·0955857	·0007320644
1367	1868689	2554497863	36·9729631	11·0982926	·0007315289
1368	1871424	2560108032	36·9864840	11·1009982	·0007309942

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1369	1874161	2565726409	37·0000000	11·1037025	·0007304602
1370	1876900	2571353000	37·0135110	11·1064054	·0007299270
1371	1879641	2576987811	37·0270172	11·1091070	·0007293946
1372	1882384	2582630848	37·0405184	11·1118073	·0007288630
1373	1885129	2588282117	37·0540146	11·1145064	·0007283321
1374	1887876	2593941624	37·0675060	11·1172041	·0007278020
1375	1890625	2599609375	37·0809924	11·1199004	·0007272727
1376	1893376	2605285376	37·0944740	11·1225955	·0007267442
1377	1896129	2610969633	37·1079506	11·1252893	·0007262164
1378	1898884	2616662152	37·1214224	11·1279817	·0007256894
1379	1901641	2622362939	37·1348893	11·1306729	·0007251632
1380	1904400	2628072000	37·1483512	11·1333628	·0007246377
1381	1907161	2633789341	37·1618084	11·1360514	·0007241130
1382	1909924	2639514968	37·1752606	11·1387386	·0007235890
1383	1912689	2645248887	37·1887079	11·1414246	·0007230658
1384	1915456	2650991104	37·2021505	11·1441093	·0007225434
1385	1918225	2656741625	37·2155881	11·1467926	·0007220217
1386	1920996	2662500456	37·2290209	11·1494747	·0007215007
1387	1923769	2668267603	37·2424489	11·1521555	·0007209805
1388	1926544	2674043072	37·2558720	11·1548350	·0007204611
1389	1929321	2679826869	37·2692903	11·1575133	·0007199424
1390	1932100	2685619000	37·2827037	11·1601903	·0007194245
1391	1934881	2691419471	37·2961124	11·1628659	·0007189073
1392	1937664	2697228288	37·3095162	11·1655403	·0007183908
1393	1940449	2703045457	37·3229152	11·1682134	·0007178751
1394	1943236	2708870984	37·3363094	11·1708852	·0007173601
1395	1946025	2714704875	37·3496988	11·1735558	·0007168459
1396	1948816	2720547136	37·3630834	11·1762250	·0007163324
1397	1951609	2726397773	37·3764632	11·1788930	·0007158196
1398	1954404	2732256792	37·3898382	11·1815598	·0007153076
1399	1957201	2738124199	37·4032084	11·1842252	·0007147963
1400	1960000	2744000000	37·4165738	11·1868894	·0007142857
1401	1962801	2749884201	37·4299345	11·1895523	·0007137759
1402	1965604	2755776808	37·4432904	11·1922139	·0007132668
1403	1968409	2761677827	37·4566416	11·1948743	·0007127584
1404	1971216	2767587264	37·4699880	11·1975334	·0007122507
1405	1974025	2773505125	37·4833296	11·2001913	·0007117438
1406	1976836	2779431416	37·4966665	11·2028479	·0007112376
1407	1979649	2785366143	37·5099987	11·2055032	·0007107321
1408	1982464	2791309312	37·5233261	11·2081573	·0007102273
1409	1985281	2797260929	37·5366487	11·2108101	·0007097232
1410	1988100	2803221000	37·5499667	11·2134617	·0007092199
1411	1990921	2809189531	37·5632799	11·2161120	·0007087172
1412	1993744	2815166528	37·5765885	11·2187611	·0007082153
1413	1996569	2821151997	37·5898922	11·2214089	·0007077141
1414	1999396	2827145944	37·6031913	11·2240554	·0007072136
1415	2002225	2833148375	37·6164857	11·2267007	·0007067138
1416	2005056	2839159296	37·6297754	11·2293448	·0007062147
1417	2007889	2845178713	37·6430604	11·2319876	·0007057163

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1418	2010724	2851206632	37·6563407	11·2346292	·0007052186
1419	2013561	2857243059	37·6696164	11·2372696	·0007047216
1420	2016400	2863288000	37·6828874	11·2399087	·0007042254
1421	2019241	2869341461	37·6961536	11·2425465	·0007037298
1422	2022084	2875403448	37·7094153	11·2451831	·0007032349
1423	2024929	2881473967	37·7226722	11·2478185	·0007027407
1424	2027776	2887553024	37·7359245	11·2504527	·0007022472
1425	2030625	2893640625	37·7491722	11·2530856	·0007017544
1426	2033476	2899736776	37·7624152	11·2557173	·0007012623
1427	2036329	2905841483	37·7756535	11·2583478	·0007007708
1428	2039184	2911954752	37·7888873	11·2609770	·0007002801
1429	2042041	2918076589	37·8021163	11·2636050	·0006997901
1430	2044900	2924207000	37·8153408	11·2662318	·0006993007
1431	2047761	2930345991	37·8285606	11·2688573	·0006988120
1432	2050624	2936493568	37·8417759	11·2714816	·0006983240
1433	2053489	2942649737	37·8549864	11·2741047	·0006978367
1434	2056356	2948814504	37·8681924	11·2767266	·0006973501
1435	2059225	2954987875	37·8813938	11·2793472	·0006968641
1436	2062096	2961169856	37·8945906	11·2819666	·0006963788
1437	2064969	2967360453	37·9077828	11·2845849	·0006958942
1438	2067844	2973559672	37·9209704	11·2872019	·0006954103
1439	2070721	2979767519	37·9341535	11·2898177	·0006949270
1440	2073600	2985984000	37·9473319	11·2924323	·0006944444
1441	2076481	2992209121	37·9605058	11·2950457	·0006939625
1442	2079364	2998442888	37·9736751	11·2976579	·0006934813
1443	2082249	3004685307	37·9868398	11·3002688	·0006930007
1444	2085136	3010936384	38·0000000	11·3028786	·0006925208
1445	2088025	3017196125	38·0131556	11·3054871	·0006920415
1446	2090916	3023464536	38·0263067	11·3080945	·0006915629
1447	2093809	3029741623	38·0394532	11·3107006	·0006910850
1448	2096704	3036027392	38·0525952	11·3133056	·0006906078
1449	2099601	3042321849	38·0657326	11·3159094	·0006901312
1450	2102500	3048625000	38·0788655	11·3185119	·0006896552
1451	2105401	3054936851	38·0919939	11·3211132	·0006891799
1452	2108304	3061257408	38·1051178	11·3237134	·0006887052
1453	2111209	3067586677	38·1182371	11·3263124	·0006882312
1454	2114116	3073924664	38·1313519	11·3289102	·0006877579
1455	2117025	3080271375	38·1444622	11·3315067	·0006872852
1456	2119936	3086626816	38·1575681	11·3341022	·0006868132
1457	2122849	3092990993	38·1706693	11·3366964	·0006863418
1458	2125764	3099363912	38·1837662	11·3392894	·0006858711
1459	2128681	3105745579	38·1968585	11·3418813	·0006854010
1460	2131600	3112136000	38·2099463	11·3444719	·0006849315
1461	2134521	3118535181	38·2230297	11·3470614	·0006844627
1462	2137444	3124943128	38·2361085	11·3496497	·0006839945
1463	2140369	3131359847	38·2491829	11·3522368	·0006835270
1464	2143296	3137785344	38·2622529	11·3548227	·0006830601
1465	2146225	3144219625	38·2753184	11·3574075	·0006825939
1466	2149156	3150662696	38·2883794	11·3599911	·0006821282

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1467	2152089	3157114563	38·3014360	11·3625735	·0006816633
1468	2155024	3163575232	38·3144881	11·3651547	·0006811989
1469	2157961	3170044709	38·3275358	11·3677347	·0006807352
1470	2160900	3176523000	38·3405790	11·3703136	·0006802721
1471	2163841	3183010111	38·3536178	11·3728914	·0006798097
1472	2166784	3189506048	38·3666522	11·3754679	·0006793478
1473	2169729	3169010817	38·3796821	11·3780433	·0006788866
1474	2172676	3202524424	38·3927076	11·3806175	·0006784261
1475	2175625	3209046875	38·4057287	11·3831906	·0006779661
1476	2178576	3215578176	38·4187454	11·3857625	·0006775068
1477	2181529	3222118333	38·4317577	11·3883332	·0006770481
1478	2184484	3228667352	38·4447656	11·3909028	·0006765900
1479	2187441	3235225239	38·4577691	11·3934712	·0006761325
1480	2190400	3241792000	38·4707681	11·3960384	·0006756757
1481	2193361	3248367641	38·4837627	11·3986045	·0006752194
1482	2196324	3254952168	38·4967530	11·4011695	·0006747638
1483	2199289	3261545587	38·5097390	11·4037332	·0006743088
1484	2202256	3268147904	38·5227206	11·4062959	·0006738544
1485	2205225	3274759125	38·5356977	11·4088574	·0006734007
1486	2208196	3281379256	38·5486705	11·4114177	·0006729475
1487	2211169	3288008303	38·5616389	11·4139769	·0006724950
1488	2214144	3294646272	38·5746030	11·4165349	·0006720430
1489	2217121	3301293169	38·5875627	11·4190918	·0006715917
1490	2220100	3307949000	38·6005181	11·4216476	·0006711409
1491	2223081	3314613771	38·6134691	11·4242022	·0006706908
1492	2226064	3321287488	38·6264158	11·4267556	·0006702413
1493	2229049	3327970157	38·6393582	11·4293079	·0006697924
1494	2232036	3334661784	38·6522962	11·4318591	·0006693440
1495	2235025	3341362375	38·6652299	11·4344092	·0006688963
1496	2238016	3348071936	38·6781593	11·4369581	·0006684492
1497	2241009	3354790473	38·6910843	11·4395059	·0006680027
1498	2244004	3361517992	38·7040050	11·4420525	·0006675567
1499	2247001	3368254499	38·7169214	11·4445980	·0006671114
1500	2250000	3375000000	38·7298335	11·4471424	·0006666667
1501	2253001	3381754501	38·7427412	11·4496857	·0006662225
1502	2256004	3388518008	38·7556447	11·4522278	·0006657790
1503	2259009	3395290527	38·7685439	11·4547688	·0006643360
1504	2262016	3402072064	38·7814389	11·4573087	·0006648936
1505	2265025	3408862625	38·7943294	11·4598474	·0006644518
1506	2268036	3415662216	38·8072158	11·4623850	·0006640106
1507	2271049	3422470843	38·8200978	11·4649215	·0006635700
1508	2274064	3429288512	38·8329757	11·4674568	·0006631300
1509	2277081	3436115229	38·8458491	11·4699911	·0006626905
1510	2280100	3442951000	38·8587184	11·4725242	·0006622517
1511	2283121	3449795831	38·8715834	11·4750562	·0006618134
1512	2286144	3456649728	38·8844442	11·4775871	·0006613757
1513	2289169	3463512697	38·8973006	11·4801169	·0006609385
1514	2292196	3470384744	38·9101529	11·4826455	·0006605020
1515	2295225	3477265875	38·9230009	11·4851731	·0006600660

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1516	2298256	3484156096	38·9358447	11·4876995	·0006596306
1517	2301289	3491055413	38·9486841	11·4902249	·0006591958
1518	2304324	3497963832	38·9615194	11·4927491	·0006587615
1519	2307361	3504881359	38·9743505	11·4952722	·0006583278
1520	2310400	3511808000	38·9871774	11·4977942	·0006578947
1521	2313441	3518743761	39·0000000	11·5003151	·0006574622
1522	2316484	3525688648	39·0128184	11·5028348	·0006570302
1523	2319529	3532642667	39·0256326	11·5053535	·0006565988
1524	2322576	3539605824	39·0384426	11·5078711	·0006561680
1525	2325625	3546578125	39·0512483	11·5103876	·0006557377
1526	2328676	3553559576	39·0640499	11·5129030	·0006553080
1527	2331729	3560550183	39·0768473	11·5154173	·0006548788
1528	2334784	3567549952	39·0896406	11·5179305	·0006544503
1529	2337841	3574558889	39·1024296	11·5204425	·0006540222
1530	2340900	3581577000	39·1152144	11·5229535	·0006535948
1531	2343961	3588604291	39·1279951	11·5254634	·0006531679
1532	2347024	3595640768	39·1407716	11·5279722	·0006527415
1533	2350089	3602686437	39·1535439	11·5304799	·0006523157
1534	2353156	3609741304	39·1663120	11·5329865	·0006518905
1535	2356225	3616805375	39·1790760	11·5354920	·0006514658
1536	2359296	3623878656	39·1918359	11·5379965	·0006510417
1537	2362369	3630961153	39·2045915	11·5404998	·0006506181
1538	2365444	3638052872	39·2173431	11·5430021	·0006501951
1539	2368521	3645153819	39·2300905	11·5455033	·0006497726
1540	2371600	3652264000	39·2428337	11·5480034	·0006493506
1541	2374681	3659383421	39·2555728	11·5505025	·0006489293
1542	2377764	3666512088	39·2683078	11·5530004	·0006485084
1543	2380849	3673650007	39·2810387	11·5554973	·0006480881
1544	2383936	3680797184	39·2937654	11·5579931	·0006476684
1545	2387025	3687953625	39·3064880	11·5604878	·0006472492
1546	2390116	3695119336	39·3192065	11·5629815	·0006468305
1547	2393209	3702294323	39·3319208	11·5654740	·0006464124
1548	2396304	3709478592	39·3446311	11·5679655	·0006459948
1549	2399401	3716672149	39·3573373	11·5704559	·0006455778
1550	2402500	3723875000	39·3700394	11·5729453	·0006451613
1551	2405601	3731087151	39·3827373	11·5754336	·0006447453
1552	2408704	3738308608	39·3954312	11·5779208	·0006443299
1553	2411809	3745539377	39·4081210	11·5804069	·0006439150
1554	2414916	3752779464	39·4208067	11·5828919	·0006435006
1555	2418025	3760028875	39·4334883	11·5853759	·0006430868
1556	2421136	3767287616	39·4461658	11·5878588	·0006426735
1557	2424249	3774555693	39·4588393	11·5903407	·0006422608
1558	2427364	3781833112	39·4715087	11·5928215	·0006418485
1559	2430481	3789119879	39·4841740	11·5953013	·0006414368
1560	2433600	3796416000	39·4968353	11·5977799	·0006410256
1561	2436721	3803721481	39·5094925	11·6002576	·0006406150
1562	2439844	3811036328	39·5221457	11·6027342	·0006402049
1563	2442969	3818360547	39·5347948	11·6052097	·0006397953
1564	2446096	3825694144	39·5474399	11·6076841	·0006393862

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1565	2449225	3833037125	39·5600809	11·6101575	·0006389776
1566	2452356	3840389496	39·5727179	11·6126299	·0006385696
1567	2455489	3847751263	39·5853508	11·6151012	·0006381621
1568	2458624	3855122432	39·5979797	11·6175715	·0006377551
1569	2461761	3862503009	39·6106046	11·6200407	·0006373486
1570	2464900	3869893000	39·6232255	11·6225088	·0006369427
1571	2468041	3877292411	39·6358424	11·6249759	·0006365372
1572	2471184	3884701248	39·6484552	11·6274420	·0006361323
1573	2474329	3892119517	39·6610640	11·6299070	·0006357279
1574	2477476	3899547224	39·6736688	11·6323710	·0006353240
1575	2480625	3906984375	39·6862696	11·6348339	·0006349026
1576	2483776	3914430976	39·6988665	11·6372957	·0006345178
1577	2486929	3921887033	39·7114593	11·6397566	·0006341154
1578	2490084	3929352552	39·7240481	11·6422164	·0006337136
1579	2493241	3936827539	39·7366329	11·6446751	·0006333122
1580	2496400	3944312000	39·7492138	11·6471329	·0006329114
1581	2499561	3951805941	39·7617907	11·6495895	·0006325111
1582	2502724	3959309368	39·7743636	11·6520452	·0006321113
1583	2505889	3966822287	39·7869325	11·6544998	·0006317119
1584	2509056	3974344704	39·7994975	11·6569534	·0006343131
1585	2512225	3981876625	39·8120585	11·6594059	·0006309148
1586	2515396	3989418056	39·8246155	11·6618574	·0006305170
1587	2518569	3996969003	39·8371686	11·6643079	·0006301197
1588	2521744	4004529472	39·8497177	11·6667574	·0006297229
1589	2524921	4012099469	39·8622628	11·6692058	·0006293266
1590	2528100	4019679000	39·8748040	11·6716532	·0006289308
1591	2531281	4027268071	39·8873413	11·6740996	·0006285355
1592	2534464	4034866688	39·8998747	11·6765449	·0006281407
1593	2537649	4042474857	39·9124041	11·6789892	·0006277464
1594	2540836	4050092584	39·9249295	11·6814325	·0006273526
1595	2544025	4057719875	39·9374511	11·6838748	·0006269592
1596	2547216	4065356736	39·9499687	11·6863161	·0006265664
1597	2550409	4073003173	39·9624824	11·6887563	·0006261741
1598	2553604	4080659192	39·9749922	11·6911955	·0006257822
1599	2556801	4088324799	39·9874980	11·6936337	·0006253909
1600	2560000	4096000000	40·0000000	11·6960709	·0006250000
1601	2563201	4103684801	40·0124980	11·6985071	·0006246096
1602	2566404	4111379208	40·0249922	11·7009422	·0006242197
1603	2569609	4119083227	40·0374824	11·7033764	·0006238303
1604	2572816	4126796864	40·0499688	11·7058095	·0006234414
1605	2576025	4134520125	40·0624512	11·7082417	·0006230530
1606	2579236	4142253016	40·0749298	11·7106728	·0006226650
1607	2582449	4149995543	40·0874045	11·7131029	·0006222775
1608	2585664	4157747712	40·0998753	11·7155320	·0006218905
1609	2588881	4165509529	40·1123423	11·7179601	·0006215040
1610	2592100	4173281000	40·1248053	11·7203872	·0006211180
1611	2595321	4181062131	40·1372645	11·7228133	·0006207325
1612	2598544	4188852928	40·1497198	11·7252384	·0006203474
1613	2601769	4196653397	40·1621713	11·7276625	·0006199628

No.	Square	Cube	Square Root	Cube Root	Reciproca.
1614	2604996	4204463544	40·1746188	11·7300855	·0006195787
1615	2608225	4212283375	40·1870626	11·7325076	·0006191950
1616	2611456	4220112896	40·1995025	11·7349286	·0006188119
1617	2614689	4227952113	40·2119385	11·7373487	·0006184292
1618	2617924	4235801032	40·2243707	11·7397677	·0006180470
1619	2621161	4243659659	40·2367990	11·7421858	·0006176652
1620	2624400	4251528000	40·2492236	11·7446029	·0006172840
1621	2627641	4259406061	40·2616443	11·7470190	·0006169031
1622	2630884	4267293848	40·2740611	11·7494341	·0006165228
1623	2634129	4275191367	40·2864742	11·7518482	·0006161429
1624	2637376	4283098624	40·2988834	11·7542613	·0006157635
1625	2640625	4291015625	40·3112888	11·7566734	·0006153846
1626	2643876	4298942376	40·3236903	11·7590846	·0006150062
1627	2647129	4306878883	40·3360881	11·7614947	·0006146282
1628	2650384	4314825152	40·3484820	11·7639039	·0006142506
1629	2653641	4322781189	40·3608721	11·7663121	·0006138735
1630	2656900	4330747000	40·3732585	11·7687193	·0006134969
1631	2660161	4338722591	40·3856410	11·7711255	·0006131208
1632	2663424	4346707968	40·3980198	11·7735306	·0006127451
1633	2666689	4354703137	40·4103947	11·7759349	·0006123699
1634	2669956	4362708104	40·4227658	11·7783381	·0006119951
1635	2673225	4370722875	40·4351332	11·7807404	·0006116208
1636	2676496	4378747456	40·4474968	11·7831417	·0006112469
1637	2679769	4386781853	40·4598566	11·7855420	·0006108735
1638	2683044	4394826072	40·4722127	11·7879414	·0006105006
1639	2686321	4402880119	40·4845649	11·7903397	·0006101281
1640	2689600	4410944000	40·4969135	11·7927371	·0006097561
1641	2692881	4419017721	40·5092582	11·7951335	·0006093845
1642	2696164	4427101288	40·5215992	11·7975289	·0006090134
1643	2699449	4435194707	40·5339364	11·7999234	·0006086427
1644	2702736	4443297984	40·5462699	11·8023169	·0006082725
1645	2706025	4451411125	40·5585996	11·8047094	·0006079027
1646	2709316	4459534136	40·5709255	11·8071010	·0006075334
1647	2712609	4467667023	40·5832477	11·8094916	·0006071645
1648	2715904	4475809792	40·5955663	11·8118812	·0006067961
1649	2719201	4483962449	40·6078810	11·8142698	·0006064281
1650	2722500	4492125000	40·6201920	11·8166576	·0006060606
1651	2725801	4500297451	40·6324993	11·8190443	·0006056935
1652	2729104	4508479808	40·6448029	11·8214301	·0006053269
1653	2732409	4516672077	40·6571027	11·8238149	·0006049607
1654	2735716	4524874264	40·6693988	11·8261987	·0006045949
1655	2739025	4533086375	40·6816912	11·8285816	·0006042296
1656	2742336	4541308416	40·6939799	11·8309634	·0006038647
1657	2745649	4549540393	40·7062648	11·8333444	·0006035003
1658	2748964	4557782312	40·7185461	11·8357244	·0006031363
1659	2752281	4566034179	40·7308237	11·8381034	·0006027728
1660	2755600	4574296000	40·7430976	11·8404815	·0006024096
1661	2758921	4582567781	40·7553677	11·8428586	·0006020470
1662	2762244	4590849528	40·7676342	11·8452348	·0006016847

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1663	2765569	4599141247	40·7798970	11·8476100	·0006013229
1664	2768896	4607442994	40·7921561	11·8499843	·0006009615
1665	2772225	4615754625	40·8044115	11·8523576	·0006006006
1666	2775556	4624076296	40·8166633	11·8547299	·0006002401
1667	2778889	4632407963	40·8289113	11·8571014	·0005998800
1668	2782224	4640749632	40·8411557	11·8594719	·0005995204
1669	2785561	4649101309	40·8533964	11·8618414	·0005991612
1670	2788900	4657463000	40·8656335	11·8642100	·0005988024
1671	2792241	4665834711	40·8778669	11·8665776	·0005984440
1672	2795584	4674216448	40·8900966	11·8689443	·0005980861
1673	2798929	4682608217	40·9023227	11·8713100	·0005977286
1674	2802276	4691010024	40·9145451	11·8736748	·0005973716
1675	2805625	4699421875	40·9267638	11·8760387	·0005970149
1676	2808976	4707843776	40·9389790	11·8784016	·0005966587
1677	2812329	4716275733	40·9511905	11·8807636	·0005963029
1678	2815684	4724717752	40·9633983	11·8831246	·0005959476
1679	2819041	4733169839	40·9756025	11·8854847	·0005955926
1680	2822400	4741632000	40·9878031	11·8878439	·0005952381
1681	2825761	4750104241	41·0000000	11·8902022	·0005948840
1682	2829124	4758586568	41·0121933	11·8925595	·0005945303
1683	2832489	4767078987	41·0243830	11·8949159	·0005941771
1684	2835856	4775581504	41·0365691	11·8972713	·0005938242
1685	2839225	4784094125	41·0487515	11·8996258	·0005934718
1686	2842596	4792616856	41·0609303	11·9019793	·0005931198
1687	2845969	4801149703	41·0731055	11·9043319	·0005927682
1688	2849344	4809692672	41·0852772	11·9066836	·0005924171
1689	2852721	4818245769	41·0974452	11·9090344	·0005920663
1690	2856100	4826809000	41·1096096	11·9113843	·0005917160
1691	2859481	4835382371	41·1217704	11·9137332	·0005913661
1692	2862864	4843965888	41·1339276	11·9160812	·0005910165
1693	2866249	4852559557	41·1460812	11·9184283	·0005906675
1694	2869636	4861163384	41·1582313	11·9207744	·0005903188
1695	2873025	4869777375	41·1703777	11·9231196	·0005899705
1696	2876416	4878401536	41·1825206	11·9254639	·0005896226
1697	2879809	4887035873	41·1946599	11·9278073	·0005892752
1698	2883204	4895680392	41·2067956	11·9301497	·0005889282
1699	2886601	4904335099	41·2189277	11·9324913	·0005885815
1700	2890000	4913000000	41·2310563	11·9348319	·0005882353
1701	2893401	4921675101	41·2431812	11·9371716	·0005878895
1702	2896804	4930360408	41·2553027	11·9395104	·0005875441
1703	2900209	4939055927	41·2674205	11·9418482	·0005871991
1704	2903616	4947761664	41·2795349	11·9441852	·0005868545
1705	2907025	4956477625	41·2916456	11·9465213	·0005865103
1706	2910436	4965203816	41·3037529	11·9488564	·0005861665
1707	2913849	4973940243	41·3158565	11·9511906	·0005858231
1708	2917264	4982686912	41·3279566	11·9535239	·0005854801
1709	2920681	4991443829	41·3400532	11·9558563	·0005851375
1710	2924100	5000211000	41·3521463	11·9581878	·0005847953
1711	2927521	5008988431	41·3642358	11·9605184	·0005844535

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1712	2930944	5017776128	41·3763217	11·9628481	·0005841121
1713	2934369	5026574097	41·3884042	11·9651768	·0005837712
1714	2937796	5035382344	41·4004831	11·9675047	·0005834306
1715	2941225	5044200875	41·4125585	11·9698317	·0005830904
1716	2944656	5053029696	41·4246304	11·9721577	·0005827506
1717	2948089	5061868813	41·4366987	11·9744829	·0005824112
1718	2951524	5070718232	41·4487636	11·9768071	·0005820722
1719	2954961	5079577959	41·4608249	11·9791304	·0005817336
1720	2958400	5088448000	41·4728827	11·9814528	·0005813953
1721	2961841	5097328361	41·4849370	11·9837744	·0005810575
1722	2965284	5106219048	41·4969878	11·9860950	·0005807201
1723	2968729	5115120067	41·5090351	11·9884148	·0005803831
1724	2972176	5124031424	41·5210790	11·9907336	·0005800464
1725	2975625	5132953125	41·5331193	11·9930516	·0005797101
1726	2979076	5141885176	41·5451561	11·9953686	·0005793743
1727	2982529	5150827583	41·5571895	11·9976848	·0005790388
1728	2985984	5159780352	41·5692194	12·0000000	·0005787037
1729	2989441	5168743489	41·5812457	12·0023144	·0005783690
1730	2992900	5177717000	41·5932686	12·0046278	·0005780347
1731	2996361	5186700891	41·6052881	12·0069404	·0005777008
1732	2999824	5195695168	41·6173041	12·0092521	·0005773672
1733	3003289	5204699837	41·6293166	12·0115629	·0005770340
1734	3006756	5213714904	41·6413256	12·0138728	·0005767013
1735	3010225	5222740375	41·6533312	12·0161818	·0005763689
1736	3013696	5231776256	41·6653333	12·0184900	·0005760369
1737	3017169	5240822553	41·6773319	12·0207973	·0005757052
1738	3020644	5249879272	41·6893271	12·0231037	·0005753740
1739	3024121	5258946419	41·7013189	12·0254092	·0005750431
1740	3027600	5268024000	41·7133072	12·0277138	·0005747126
1741	3031081	5277112021	41·7252921	12·0300175	·0005743825
1742	3034564	5286210488	41·7372735	12·0323204	·0005740528
1743	3038049	5295319407	41·7492515	12·0346223	·0005737235
1744	3041536	5304438784	41·7612260	12·0369233	·0005733945
1745	3045025	5313568625	41·7731971	12·0392235	·0005730659
1746	3048516	5322708936	41·7851648	12·0415229	·0005727377
1747	3052009	5331859723	41·7971291	12·0438213	·0005724098
1748	3055504	5341020992	41·8090899	12·0461189	·0005720824
1749	3059001	5350192749	41·8210473	12·0484156	·0005717553
1750	3062500	5359375000	41·8330013	12·0507114	·0005714286
1751	3066001	5368567751	41·8449519	12·0530063	·0005711022
1752	3069504	5377771008	41·8568991	12·0553003	·0005707763
1753	3073009	5386984777	41·8688428	12·0575935	·0005704507
1754	3076516	5396209064	41·8807832	12·0598859	·0005701254
1755	3080025	5405443875	41·8927201	12·0621773	·0005698006
1756	3083536	5414689216	41·9046537	12·0644679	·0005694761
1757	3087049	5423945093	41·9165838	12·0667576	·0005691520
1758	3090564	5433211512	41·9285106	12·0690464	·0005688282
1759	3094081	5442488479	41·9404339	12·0713344	·0005685048
1760	3097600	5451776000	41·9523539	12·0736215	·0005681818

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1761	3101121	5461074081	41·9642705	12·0759077	·0005678592
1762	3104644	5470382728	41·9761837	12·0781930	·0005675369
1763	3108169	5479701947	41·9880935	12·0804775	·0005672150
1764	3111696	5489031744	42·0000000	12·0827612	·0005668934
1765	3115225	5498372125	42·0119031	12·0850439	·0005665722
1766	3118756	5507723096	42·0238028	12·0873258	·0005662514
1767	3122289	5517084663	42·0356991	12·0896069	·0005659310
1768	3125824	5526456832	42·0475921	12·0918870	·0005656109
1769	3129361	5535839609	42·0594817	12·0941664	·0005652911
1770	3132900	5545233000	42·0713679	12·0964449	·0005649718
1771	3136441	5554637011	42·0832508	12·0987226	·0005646527
1772	3139984	5564051648	42·0951304	12·1009993	·0005643341
1773	3143529	5573476917	42·1070065	12·1032753	·0005640158
1774	3147076	5582912824	42·1188794	12·1055503	·0005636979
1775	3150625	5592359375	42·1307488	12·1078245	·0005633803
1776	3154176	5601816576	42·1426150	12·1100979	·0005630631
1777	3157729	5611284433	42·1544778	12·1123704	·0005627462
1778	3161284	5620762952	42·1663373	12·1146420	·0005624297
1779	3164841	5630252139	42·1781934	12·1169128	·0005621135
1780	3168400	5639752000	42·1900462	12·1191827	·0005617978
1781	3171961	5649262541	42·2018957	12·1214518	·0005614823
1782	3175524	5658783768	42·2137418	12·1237200	·0005611672
1783	3179089	5668315687	42·2255846	12·1259874	·0005608525
1784	3182656	5677858304	42·2374242	12·1282539	·0005605381
1785	3186225	5687411625	42·2492603	12·1305197	·0005602241
1786	3189796	5696975656	42·2610932	12·1327845	·0005599104
1787	3193369	5706550403	42·2729227	12·1350485	·0005595971
1788	3196944	5716135872	42·2847490	12·1373117	·0005592841
1789	3200521	5725732069	42·2965719	12·1395740	·0005589715
1790	3204100	5735339000	42·3083916	12·1418355	·0005586592
1791	3207681	5744956671	42·3202079	12·1440961	·0005583473
1792	3211264	5754585088	42·3320210	12·1463559	·0005580357
1793	3214849	5764224257	42·3438307	12·1486148	·0005577245
1794	3218436	5773874184	42·3556371	12·1508729	·0005574136
1795	3222025	5783534875	42·3674403	12·1531302	·0005571031
1796	3225616	5793206336	42·3792402	12·1553866	·0005567929
1797	3229209	5802888573	42·3910368	12·1576422	·0005564830
1798	3232804	5812581592	42·4028301	12·1598970	·0005561735
1799	3236401	5822285399	42·4146201	12·1621509	·0005558644
1800	3240000	5832000000	42·4264069	12·1644040	·0005555556
1801	3243601	5841725401	42·4381903	12·1666562	·0005552471
1802	3247204	5851461608	42·4499705	12·1689076	·0005549390
1803	3250809	5861208627	42·4617475	12·1711582	·0005546312
1804	3254416	5870966464	42·4735212	12·1734079	·0005543237
1805	3258025	5880735125	42·4852916	12·1756569	·0005540166
1806	3261636	5890514616	42·4970587	12·1779050	·0005537099
1807	3265249	5900304943	42·5088226	12·1801522	·0005534034
1808	3268864	5910106112	42·5205833	12·1823987	·0005530973
1809	3272481	5919918129	42·5323406	12·1846443	·0005527916

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1810	3276100	5929741000	42·5440948	12·1868891	·0005524862
1811	3279721	5939574731	42·5558456	12·1891331	·0005521811
1812	3283344	5949419328	42·5675933	12·1913762	·0005518764
1813	3286969	5959274797	42·5793377	12·1936185	·0005515720
1814	3290596	5969141144	42·5910789	12·1958599	·0005512679
1815	3294225	5979018375	42·6028168	12·1981006	·0005509642
1816	3297856	5988906496	42·6145515	12·2003404	·0005506608
1817	3301489	5998805513	42·6262829	12·2025794	·0005503577
1818	3305124	6008715432	42·6380112	12·2048176	·0005500550
1819	3308761	6018636259	42·6497362	12·2070549	·0005497526
1820	3312400	6028568000	42·6614580	12·2092915	·0005494505
1821	3316041	6038510661	42·6731766	12·2115272	·0005491488
1822	3319684	6048464248	42·6848919	12·2137621	·0005488474
1823	3323329	6058428767	42·6966040	12·2159962	·0005485464
1824	3326976	6068404224	42·7083130	12·2182295	·0005482456
1825	3330625	6078390625	42·7200187	12·2204620	·0005479452
1826	3334276	6088387976	42·7317212	12·2226936	·0005476451
1827	3337929	6098396283	42·7434206	12·2249244	·0005473454
1828	3341584	6108415552	42·7551167	12·2271544	·0005470460
1829	3345241	6118445789	42·7668095	12·2293836	·0005467469
1830	3348900	6128487000	42·7784992	12·2316120	·0005464481
1831	3352561	6138539191	42·7901858	12·2338396	·0005461496
1832	3356224	6148602368	42·8018691	12·2360663	·0005458515
1833	3359889	6158676537	42·8135492	12·2382923	·0005455537
1834	3363556	6168761704	42·8252262	12·2405174	·0005452563
1835	3367225	6178857875	42·8368999	12·2427418	·0005449591
1836	3370896	6188965056	42·8485706	12·2449653	·0005446623
1837	3374569	6199083253	42·8602380	12·2471880	·0005443658
1838	3378244	6209212472	42·8719022	12·2494099	·0005440696
1839	3381921	6219352719	42·8835633	12·2516310	·0005437738
1840	3385600	6229504000	42·8952212	12·2538513	·0005434783
1841	3389281	6239666321	42·9068759	12·2560708	·0005431831
1842	3392964	6249839688	42·9185275	12·2582895	·0005428882
1843	3396649	6260024107	42·9301759	12·2605074	·0005425936
1844	3400336	6270219584	42·9418211	12·2627245	·0005422993
1845	3404025	6280426125	42·9534632	12·2649408	·0005420054
1846	3407716	6290643736	42·9651021	12·2671563	·0005417118
1847	3411409	6300872423	42·9767379	12·2693710	·0005414185
1848	3415104	6311112192	42·9883705	12·2715849	·0005411255
1849	3418801	6321363049	43·0000000	12·2737980	·0005408329
1850	3422500	6331625000	43·0116263	12·2760103	·0005405405
1851	3426201	6341898051	43·0232495	12·2782218	·0005402485
1852	3429904	6352182208	43·0348696	12·2804325	·0005399568
1853	3433609	6362477477	43·0464865	12·2826424	·0005396654
1854	3437316	6372783864	43·0581003	12·2848515	·0005393743
1855	3441025	6383101375	43·0697109	12·2870598	·0005390836
1856	3444736	6393430016	43·0813185	12·2892673	·0005387931
1857	3448449	6403769793	43·0929228	12·2914740	·0005385030
1858	3452164	6414120712	43·1045241	12·2936800	·0005382131

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1859	3455881	6424482779	43·1161223	12·2958851	·0005379236
1860	3459600	6434856000	43·1277173	12·2980895	·0005376344
1861	3463321	6445240381	43·1393092	12·3002930	·0005373455
1862	3467044	6455635928	43·1508980	12·3024958	·0005370569
1863	3470769	6466042647	43·1624837	12·3046978	·0005367687
1864	3474496	6476460544	43·1740663	12·3068990	·0005364807
1865	3478225	6486889625	43·1856458	12·3090994	·0005361930
1866	3481956	6497329896	43·1972221	12·3112991	·0005359057
1867	3485689	6507781363	43·2087954	12·3134979	·0005356186
1868	3489424	6518244032	43·2203656	12·3156959	·0005353319
1869	3493161	6528717909	43·2319326	12·3178932	·0005350455
1870	3496900	6539203000	43·2434966	12·3200897	·0005347594
1871	3500641	6549699311	43·2550575	12·3222854	·0005344735
1872	3504384	6560206848	43·2666153	12·3244803	·0005341880
1873	3508129	6570725617	43·2781700	12·3266744	·0005339028
1874	3511876	6581255624	43·2897216	12·3288678	·0005336179
1875	3515625	6591796875	43·3012702	12·3310604	·0005333333
1876	3519376	6602349376	43·3128157	12·3332522	·0005330490
1877	3523129	6612913133	43·3243580	12·3354432	·0005327651
1878	3526884	6623488152	43·3358973	12·3376334	·0005324814
1879	3530641	6634074439	43·3474336	12·3398229	·0005321980
1880	3534400	6644672000	43·3589668	12·3420116	·0005319149
1881	3538161	6655280841	43·3704969	12·3441995	·0005316321
1882	3541924	6665900968	43·3820239	12·3463866	·0005313496
1883	3545689	6676532387	43·3935479	12·3485730	·0005310674
1884	3549456	6687175104	43·4050688	12·3507586	·0005307856
1885	3553225	6697829125	43·4165867	12·3529434	·0005305040
1886	3556996	6708494456	43·4281015	12·3551274	·0005302227
1887	3560769	6719171103	43·4396132	12·3573107	·0005299417
1888	3564544	6729859072	43·4511220	12·3594932	·0005296610
1889	3568321	6740558369	43·4626276	12·3616749	·0005293806
1890	3572100	6751269000	43·4741302	12·3638559	·0005291005
1891	3575881	6761990971	43·4856298	12·3660361	·0005288207
1892	3579664	6772724288	43·4971263	12·3682155	·0005285412
1893	3583449	6783468957	43·5086198	12·3703941	·0005282620
1894	3587236	6794224984	43·5201103	12·3725721	·0005279831
1895	3591025	6804992375	43·5315977	12·3747492	·0005277045
1896	3594816	6815771136	43·5430821	12·3769255	·0005274262
1897	3598609	6826561273	43·5545635	12·3791011	·0005271481
1898	3602404	6837362792	43·5660418	12·3812759	·0005268704
1899	3606201	6848175699	43·5775171	12·3834500	·0005265929
1900	3610000	6859000000	43·5889894	12·3856233	·0005263158
1901	3613801	6869835701	43·6004587	12·3877959	·0005260389
1902	3617604	6880682808	43·6119249	12·3899676	·0005257624
1903	3621409	6891541327	43·6233882	12·3921386	·0005254861
1904	3625216	6902411264	43·6348485	12·3943089	·0005252101
1905	3629025	6913292625	43·6463057	12·3964784	·0005249344
1906	3632836	6924185416	43·6577599	12·3986471	·0005246590
1907	3636649	6935089643	43·6692111	12·4008151	·0005243838

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1908	3640464	6946005312	43·6806593	12·4029823	·0005241090
1909	3644281	6956932429	43·6921045	12·4051488	·0005238345
1910	3648100	6967871000	43·7035467	12·4073145	·0005235602
1911	3651921	6978821031	43·7149860	12·4094794	·0005232862
1912	3655744	6989782528	43·7264222	12·4116436	·0005230126
1913	3659569	7000755497	43·7378554	12·4138070	·0005227392
1914	3663396	7011739944	43·7492857	12·4159697	·0005224660
1915	3667225	7022735875	43·7607129	12·4181316	·0005221932
1916	3671056	7033743296	43·7721373	12·4202928	·0005219207
1917	3674889	7044762213	43·7835585	12·4224533	·0005216484
1918	3678724	7055792632	43·7949768	12·4246129	·0005213764
1919	3682561	7066834559	43·8063922	12·4267719	·0005211047
1920	3686400	7077888000	43·8178046	12·4289300	·0005208333
1921	3690241	7088952961	43·8292140	12·4310875	·0005205622
1922	3694084	7100029448	43·8406204	12·4332441	·0005202914
1923	3697929	7111117467	43·8520239	12·4354001	·0005200208
1924	3701776	7122217024	43·8634244	12·4375552	·0005197505
1925	3705625	7133328125	43·8748219	12·4397097	·0005194805
1926	3709476	7144450776	43·8862165	12·4418634	·0005192108
1927	3713329	7155584983	43·8976081	12·4440163	·0005189414
1928	3717184	7166730752	43·9089968	12·4461685	·0005186722
1929	3721041	7177888089	43·9203725	12·4483200	·0005184033
1930	3724900	7189057000	43·9317652	12·4504707	·0005181347
1931	3728761	7200237491	43·9431451	12·4526206	·0005178664
1932	3732624	7211429568	43·9545220	12·4547699	·0005175983
1933	3736489	7222633237	43·9658959	12·4569184	·0005173306
1934	3740356	7233848504	43·9772668	12·4590661	·0005170631
1935	3744225	7245075375	43·9886349	12·4612131	·0005167959
1936	3748096	7256313856	44·0000000	12·4633594	·0005165289
1937	3751969	7267563953	44·0113622	12·4655049	·0005162623
1938	3755844	7278825672	44·0227214	12·4676497	·0005159959
1939	3759721	7290099019	44·0340777	12·4697937	·0005157298
1940	3763600	7301384000	44·0454311	12·4719370	·0005154639
1941	3767481	7312680621	44·0567815	12·4740796	·0005151984
1942	3771364	7323988888	44·0681291	12·4762214	·0005149331
1943	3775249	7335308807	44·0794737	12·4783625	·0005146680
1944	3779136	7346640384	44·0908154	12·4805029	·0005144033
1945	3783025	7357983625	44·1021541	12·4826426	·0005141388
1946	3786916	7369338536	44·1134900	12·4847815	·0005138746
1947	3790809	7380705123	44·1248229	12·4869197	·0005136107
1948	3794704	7392083392	44·1361530	12·4890571	·0005133470
1949	3798601	7403473349	44·1474801	12·4911938	·0005130836
1950	3802500	7414875000	44·1588043	12·4933298	·0005128205
1951	3806401	7426288351	44·1701256	12·4954651	·0005125577
1952	3810304	7437713408	44·1814441	12·4975995	·0005122951
1953	3814209	7449150177	44·1027596	12·4997333	·0005120328
1954	3818116	7460598664	44·2040722	12·5018664	·0005117707
1955	3822025	7472058875	44·2153819	12·5039988	·0005115090
1956	3825936	7483530816	44·2266888	12·5061304	·0005112474

No.	Square	Cube	Square Root	Cube Root	Reciprocal
1957	3829849	7495014493	44·2379927	12·5082612	·0005109862
1958	3833764	7506509912	44·2492938	12·5103914	·0005107252
1959	3837681	7518017079	44·2605919	12·5125208	·0005104645
1960	3841600	7529536000	44·2718872	12·5146495	·0005102041
1961	3845521	7541066681	44·2831797	12·5167775	·0005099439
1962	3849444	7552609128	44·2944692	12·5189047	·0005096840
1963	3853369	7564163347	44·3057558	12·5210313	·0005094244
1964	3857296	7575729344	44·3170396	12·5231571	·0005091650
1965	3861225	7587307125	44·3283205	12·5252822	·0005089059
1966	3865156	7598896696	44·3395985	12·5274065	·0005086470
1967	3869089	7610498063	44·3508737	12·5295302	·0005083884
1968	3873024	7622111232	44·3621460	12·5316531	·0005081301
1969	3876961	7633736209	44·3734155	12·5337753	·0005078720
1970	3880900	7645373000	44·3846820	12·5358968	·0005076142
1971	3884841	7657021611	44·3959457	12·5380176	·0005073567
1972	3888784	7668682048	44·4072066	12·5401377	·0005070994
1973	3892729	7680354317	44·4184646	12·5422570	·0005068424
1974	3896676	7692038424	44·4297198	12·5443757	·0005065856
1975	3900625	7703734375	44·4409720	12·5464936	·0005063291
1976	3904576	7715442176	44·4522215	12·5486107	·0005060729
1977	3908529	7727161833	44·4634681	12·5507272	·0005058169
1978	3912484	7738893352	44·4747119	12·5528430	·0005055612
1979	3916441	7750636739	44·4859528	12·5549580	·0005053057
1980	3920400	7762392000	44·4971909	12·5570723	·0005050505
1981	3924361	7774159141	44·5084262	12·5591860	·0005047956
1982	3928324	7785938168	44·5196586	12·5612989	·0005045409
1983	3932289	7797729087	44·5308881	12·5634111	·0005042864
1984	3936256	7809531904	44·5421149	12·5655226	·0005040323
1985	3940225	7821346625	44·5533388	12·5676334	·0005037783
1986	3944196	7833173256	44·5645599	12·5697435	·0005035247
1987	3948169	7845011803	44·5757781	12·5718529	·0005032713
1988	3952144	7856862272	44·5869936	12·5739615	·0005030181
1989	3956121	7868724669	44·5982062	12·5760695	·0005027652
1990	3960100	7880599000	44·6094160	12·5781767	·0005025126
1991	3964081	7892485271	44·6206230	12·5802832	·0005022602
1992	3968064	7904383488	44·6318272	12·5823891	·0005020080
1993	3972049	7916293657	44·6430286	12·5844942	·0005017561
1994	3976036	7928215784	44·6542271	12·5865987	·0005015045
1995	3980025	7940149875	44·6654228	12·5887024	·0005012531
1996	3984016	7952095936	44·6766158	12·5908054	·0005010020
1997	3988009	7964053973	44·6878059	12·5929078	·0005007511
1998	3992004	7976023992	44·6989933	12·5950094	·0005005005
1999	3996001	7988005999	44·7101778	12·5971103	·0005002501
2000	4000000	8000000000	44·7213596	12·5992105	·0005000000
2001	4004001	8012006001	44·7325385	12·6013101	·0004997501
2002	4008004	8024024008	44·7437146	12·6034089	·0004995005
2003	4012009	8036054027	44·7548880	12·6055070	·0004992511
2004	4016016	8048096064	44·7660586	12·6076044	·0004990020
2005	4020025	8060150125	44·7772264	12·6097011	·0004987531

No.	Square	Cube	Square Root	Cube Root	Reciprocal
2006	4024036	8072216216	44·7883913	12·6117971	·0004985045
2007	4028049	8084294343	44·7995535	12·6138924	·0004982561
2008	4032064	8096384512	44·8107130	12·6159870	·0004980080
2009	4036081	8108486729	44·8218697	12·6180810	·0004977601
2010	4040100	8120601000	44·8330235	12·6201743	·0004975124
2011	4044121	8132727331	44·8441746	12·6222669	·0004972650
2012	4048144	8144865728	44·8553230	12·6243587	·0004970179
2013	4052169	8157016197	44·8664685	12·6264499	·0004967710
2014	4056196	8169178744	44·8776113	12·6285404	·0004965243
2015	4060225	8181353375	44·8887514	12·6306301	·0004962779
2016	4064256	8193540096	44·8998886	12·6327192	·0004060317
2017	4068289	8205738913	44·9110231	12·6348076	·0004957858
2018	4072324	8217949832	44·9221549	12·6368953	·0004955401
2019	4076361	8230172859	44·9332839	12·6389823	·0004952947
2020	4080400	8242408000	44·9444101	12·6410687	·0004950495
2021	4084441	8254655261	44·9555336	12·6431543	·0004948046
2022	4088484	8266914648	44·9666543	12·6452393	·0004945598
2023	4092529	8279186167	44·9777723	12·6473235	·0004943154
2024	4096576	8291469824	44·9888875	12·6494071	·0004940711
2025	4100625	8303765625	45·0000000	12·6514900	·0004938272
2026	4104676	8316073576	45·0111097	12·6535722	·0004935834
2027	4108729	8328393683	45·0222167	12·6556538	·0004933399
2028	4112784	8340725952	45·0333210	12·6577346	·0004930966
2029	4116841	8353070389	45·0444225	12·6598148	·0004928536
2030	4120900	8365427000	45·0555213	12·6618943	·0004926108
2031	4124961	8377795791	45·0666173	12·6639731	·0004923683
2032	4129024	8390176768	45·0777107	12·6660512	·0004921260
2033	4133089	8402569937	45·0888013	12·6681286	·0004918839
2034	4137156	8414975304	45·0998891	12·6702053	·0004916421
2035	4141225	8427392875	45·1109743	12·6722814	·0004914005
2036	4145296	8439822656	45·1220567	12·6743567	·0004911591
2037	4149369	8452264653	45·1331364	12·6764314	·0004909180
2038	4153444	8464718872	45·1442134	12·6785054	·0004906771
2039	4157521	8477185319	45·1552876	12·6805788	·0004904365
2040	4161600	8489664000	45·1663592	12·6826514	·0004901961
2041	4165681	8502154921	45·1774280	12·6847234	·0004899559
2042	4169764	8514658088	45·1884941	12·6867947	·0004897160
2043	4173849	8527173507	45·1995575	12·6888654	·0004894762
2044	4177936	8539701184	45·2106182	12·6909354	·0004892368
2045	4182025	8552241125	45·2216762	12·6930047	·0004889976
2046	4186116	8564793336	45·2327315	12·6950733	·0004887586
2047	4190209	8577357823	45·2437841	12·6971412	·0004885198
2048	4194304	8589934592	45·2548340	12·6992084	·0004882813
2049	4198401	8602523649	45·2658812	12·7012750	·0004880429
2050	4202500	8615125000	45·2769257	12·7033409	·0004878049
2051	4206601	8627738651	45·2879675	12·7054061	·0004875670
2052	4210704	8640364608	45·2990066	12·7074707	·0004873294
2053	4214809	8653002877	45·3100430	12·7095346	·0004870921
2054	4218916	8665653464	45·3210768	12·7115978	·0004868549

No.	Square	Cube	Square Root	Cube Root	Reciprocal
2055	4223025	8678316375	45·3321078	12·7136603	·0004866180
2056	4227136	8690991616	45·3431362	12·7157222	·0004863813
2057	4231249	8703679193	45·3541619	12·7177835	·0004861449
2058	4235364	8716379112	45·3651849	12·7198441	·0004859086
2059	4239481	8729091379	45·3762052	12·7219040	·0004856727
2060	4243600	8741816000	45·3872229	12·7239632	·0004854369
2061	4247721	8754552981	45·3982378	12·7260218	·0004852014
2062	4251844	8767302328	45·4092501	12·7280797	·0004849661
2063	4255969	8780064047	45·4202598	12·7301370	·0004847310
2064	4260096	8792838144	45·4312668	12·7321935	·0004844961
2065	4264225	8805624625	45·4422711	12·7342494	·0004842615
2066	4268356	8818423496	45·4532727	12·7363046	·0004840271
2067	4272489	8831234763	45·4642717	12·7383592	·0004837929
2068	4276624	8844058432	45·4752680	12·7404131	·0004835590
2069	4280761	8856894509	45·4862616	12·7424664	·0004833253
2070	4284900	8869743000	45·4972526	12·7445189	·0004830918
2071	4289041	8882603911	45·5082410	12·7465709	·0004828585
2072	4293184	8895477248	45·5192267	12·7486222	·0004826255
2073	4297329	8908363017	45·5302097	12·7506728	·0004823927
2074	4301476	8921261224	45·5411901	12·7527227	·0004821601
2075	4305625	8934171875	45·5521679	12·7547721	·0004819277
2076	4309776	8947094976	45·5631430	12·7568207	·0004816956
2077	4313929	8960030533	45·5741155	12·7588687	·0004814636
2078	4318084	8972978552	45·5850853	12·7609160	·0004812320
2079	4322241	8985939039	45·5960525	12·7629627	·0004810005
2080	4326400	8998912000	45·6070170	12·7650087	·0004807692
2081	4330561	9011897441	45·6179789	12·7670540	·0004805382
2082	4334724	9024895368	45·6289382	12·7690987	·0004803074
2083	4338889	9037905787	45·6398948	12·7711427	·0004800768
2084	4343056	9050928704	45·6508488	12·7731861	·0004798464
2085	4347225	9063964125	45·6618002	12·7752288	·0004796163
2086	4351396	9077012056	45·6727490	12·7772709	·0004793864
2087	4355569	9090072503	45·6836951	12·7793123	·0004791567
2088	4359744	9103145472	45·6946386	12·7813531	·0004789272
2089	4363921	9116230969	45·7055795	12·7833932	·0004786979
2090	4368100	9129329000	45·7165178	12·7854326	·0004784689
2091	4372281	9142439571	45·7274534	12·7874714	·0004782401
2092	4376464	9155562688	45·7383865	12·7895096	·0004780115
2093	4380649	9168698357	45·7493169	12·7915471	·0004777831
2094	4384836	9181846584	45·7602447	12·7935840	·0004775549
2095	4389025	9195007375	45·7711699	12·7956202	·0004773270
2096	4393216	9208180736	45·7820926	12·7976558	·0004770992
2097	4397409	9221366673	45·7930126	12·7996907	·0004768717
2098	4401604	9234565192	45·8039299	12·8017250	·0004766444
2099	4405801	9247776299	45·8148447	12·8037586	·0004764173
2100	4410000	9261000000	45·8257569	12·8057916	·0004761905
2101	4414201	9274236301	45·8366665	12·8078239	·0004759638
2102	4418404	9287485208	45·8475735	12·8098556	·0004757374
2103	4422609	9300746727	45·8584779	12·8118866	·0004755112

No.	Square	Cube	Square Root	Cube Root	Reciprocal
2104	4426816	9314020864	45·8693798	12·8139170	·0004752852
2105	4431025	9327307625	45·8802790	12·8159468	·0004750594
2106	4435236	9340607016	45·8911756	12·8179759	·0004748338
2107	4439449	9353919043	45·9020696	12·8200044	·0004746084
2108	4443664	9367243712	45·9129611	12·8220323	·0004743833
2109	4447881	9380581029	45·9238500	12·8240595	·0004741584
2110	4452100	9393931000	45·9347363	12·8260861	·0004739336
2111	4456321	9407293631	45·9456200	12·8281120	·0004737091
2112	4460544	9420668928	45·9565012	12·8301373	·0004734848
2113	4464769	9434056897	45·9673798	12·8321620	·0004732608
2114	4468996	9447457544	45·9782557	12·8341860	·0004730369
2115	4473225	9460870875	45·9891291	12·8362094	·0004728132
2116	4477456	9474296896	46·0000000	12·8382321	·0004725898
2117	4481689	9487735613	46·0108683	12·8402542	·0004723666
2118	4485924	9501187032	46·0217340	12·8422756	·0004721435
2119	4490161	9514651159	46·0325971	12·8442964	·0004719207
2120	4494400	9528128000	46·0434577	12·8463166	·0004716981
2121	4498641	9541617561	46·0543158	12·8483361	·0004714757
2122	4502884	9555119848	46·0651712	12·8503551	·0004712535
2123	4507129	9568634867	46·0760241	12·8523733	·0004710316
2124	4511376	9582162624	46·0868745	12·8543910	·0004708098
2125	4515625	9595703125	46·0977223	12·8564080	·0004705882
2126	4519876	9609256376	46·1085675	12·8584243	·0004703669
2127	4524129	9622822383	46·1194102	12·8604401	·0004701457
2128	4528384	9636401152	46·1302504	12·8624552	·0004699248
2129	4532641	9649992689	46·1410880	12·8644697	·0004697041
2130	4536900	9663597000	46·1519230	12·8664835	·0004694836
2131	4541161	9677214091	46·1627555	12·8684967	·0004692633
2132	4545424	9690843968	46·1735855	12·8705093	·0004690432
2133	4549689	9704486637	46·1844130	12·8725213	·0004688233
2134	4553956	9718142104	46·1952378	12·8745326	·0004686036
2135	4558225	9731810375	46·2060602	12·8765433	·0004683841
2136	4562496	9745491456	46·2168800	12·8785534	·0004681648
2137	4566769	9759185353	46·2276973	12·8805628	·0004679457
2138	4571044	9772892072	46·2385121	12·8825717	·0004677268
2139	4575321	9786611619	46·2493243	12·8845199	·0004675082
2140	4579600	9800344000	46·2601340	12·8865874	·0004672897
2141	4583881	9814089221	46·2709412	12·8885944	·0004670715
2142	4588164	9827847288	46·2817459	12·8906007	·0004668534
2143	4592449	9841618207	46·2925480	12·8926064	·0004666356
2144	4596736	9855401984	46·3033476	12·8946115	·0004664179
2145	4601025	9869198625	46·3141447	12·8966159	·0004662005
2146	4605316	9883008136	46·3249393	12·8986197	·0004659832
2147	4609609	9896830523	46·3357314	12·9006229	·0004657662
2148	4613904	9910665792	46·3465209	12·9026255	·0004655493
2149	4618201	9924513949	46·3573079	12·9046275	·0004653327
2150	4622500	9938375000	46·3680924	12·9066288	·0004651163
2151	4626801	9952248951	46·3788745	12·9086295	·0004649000
2152	4631104	9966135808	46·3896540	12·9106296	·0004646840

No.	Square	Cube	Square Root	Cube Root	Reciprocal
2153	4635409	9980035577	46·4004310	12·9126291	·0004644682
2154	4639716	9993948264	46·4112055	12·9146279	·0004642526
2155	4644025	10007873875	46·4219775	12·9166262	·0004640371
2156	4648336	10021812416	46·4327471	12·9186238	·0004638219
2157	4652649	10035763893	46·4435141	12·9206208	·0004636069
2158	4656964	10049728312	46·4542786	12·9226172	·0004633920
2159	4661281	10063705679	46·4650406	12·9246129	·0004631774
2160	4665600	10077696000	46·4758002	12·9266081	·0004629630
2161	4669921	10091699281	46·4865572	12·9286027	·0004627487
2162	4674244	10105715528	46·4973118	12·9305966	·0004625347
2163	4678569	10119744747	46·5080638	12·9325899	·0004623209
2164	4682896	10133786944	46·5188134	12·9345827	·0004621072
2165	4687225	10147842125	46·5295605	12·9365747	·0004618938
2166	4691556	10161910296	46·5403051	12·9385662	·0004616805
2167	4695889	10175991463	46·5510472	12·9405570	·0004614675
2168	4700224	10190085632	46·5617869	12·9425472	·0004612546
2169	4704561	10204192809	46·5725241	12·9445369	·0004610420
2170	4708900	10218313000	46·5832588	12·9465259	·0004608295
2171	4713241	10232446211	46·5939910	12·9485143	·0004606172
2172	4717584	10246592448	46·6047208	12·9505021	·0004604052
2173	4721929	10260751717	46·6154481	12·9524893	·0004601933
2174	4726276	10274924024	46·6261729	12·9544759	·0004599816
2175	4730625	10289109375	46·6368953	12·9564618	·0004597701
2176	4734976	10303307776	46·6476152	12·9584472	·0004595588
2177	4739329	10317519233	46·6583326	12·9604319	·0004593477
2178	4743684	10331743752	46·6690476	12·9624161	·0004591368
2179	4748041	10345981339	46·6797601	12·9643996	·0004589261
2180	4752400	10360232000	46·6904701	12·9663826	·0004587156
2181	4756761	10374495741	46·7011777	12·9683649	·0004585053
2182	4761124	10388772568	46·7118829	12·9703466	·0004582951
2183	4765489	10403062487	46·7225855	12·9723277	·0004580852
2184	4769856	10417365504	46·7332858	12·9743082	·0004578755
2185	4774225	10431681625	46·7439836	12·9762881	·0004576659
2186	4778596	10446010856	46·7546789	12·9782674	·0004574565
2187	4782969	10460353203	46·7653718	12·9802461	·0004572474
2188	4787344	10474708672	46·7760623	12·9822242	·0004570384
2189	4791721	10489077269	46·7867503	12·9842017	·0004568296
2190	4796100	10503459000	46·7974358	12·9861786	·0004566210
2191	4800481	10517853871	46·8081189	12·9881549	·0004564126
2192	4804864	10532261888	46·8187996	12·9901306	·0004562044
2193	4809249	10546683057	46·8294779	12·9921057	·0004559964
2194	4813636	10561117384	46·8401537	12·9940802	·0004557885
2195	4818025	10575564875	46·8508271	12·9960540	·0004555809
2196	4822416	10590025536	46·8614981	12·9980273	·0004553734
2197	4826809	10604499373	46·8721666	13·0000000	·0004551661
2198	4831204	10618986392	46·8828327	13·0019721	·0004549591
2199	4835601	10633486599	46·8934963	13·0039436	·0004547522
2200	4840000	10648000000	46·9041576	13·0059145	·0004545455
2201	4844401	10662526601	46·9148164	13·0078848	·0004543389

USEFUL INFORMATION ABOUT WATER.

Water is incompressible, or nearly so, showing no sensible change of volume under changes of pressure.

The pressure of a perfect fluid on any surface with which it is in contact is perpendicular to the surface.

The pressure of a fluid at any point of a surface is the pressure per unit area.

Any pressure applied at the surface of a fluid is transmitted equally to all parts of the fluid.

The pressure of water at rest under gravity increases uniformly with the distance; that is, the difference of pressure at any two points varies as the vertical distance between the points.

The free surface of a liquid at rest under gravity is a horizontal plane.

One cubic foot of water contains about 7.48 gallons.

One cubic foot of pure water at a temperature of 60 degrees Fahr., weighs 62.366 pounds.

One U. S. gallon of pure water at a temperature of 60 degrees Fahr., weighs 8.331 pounds.

The amount of water required to fill an ordinary automatic sprinkler system is about 1 gallon per sprinkler. This includes riser and all distribution pipes, but does not include ground mains from pump or city supply to base of riser.

This figure (one gallon per head) applies especially to systems piped from the center with 75 to 150 heads on each floor.

If system of 150 sprinkler heads is fed from end instead of center, contents will be about 1¼ gallons per head.

For large systems with 6-inch rider and about 250 heads per floor, contents, if riser is in center, will be about 1¼ gallons per head, and if riser is at one end, will be 1½ gallons per head.

SPECIFICATIONS FOR STEAM FIRE PUMPS.

AMENDMENTS.

Adopted by the National Fire Protection Association, 1907.

(Page 115, fourth paragraph, second line).

Change to read: of 34½ lbs. of water per hour, etc.

(Page 118, first paragraph, second line).

5. *Capacity Plate.*

b. Change to read: at least 85 per cent. aluminum, etc.

NOTE.—This per cent. of aluminum is considered necessary to guard against tarnishing.

(Page 120, new note).

8. *Steam Cylinders.*

d. Add: Note.—The slight beveling of piston face edges may be considered as the equivalent of this.

(Page 121, fifth paragraph, third line).

12. *Steam Clearance Space.*

a. Change clause in second parenthesis to read: Contact stroke should overrun nominal stroke at each end about ½-inch.

NOTE.—It is not found practicable to run full stroke under fire conditions with a much less clearance and receive the desired benefit from the cushion ports.

(Page 122, third paragraph).

13. *Steam Pistons.*

b. Change to read: The thickness of piston should be about one-fourth of its diameter. If solid, walls should be not less than ½-inch thick, and special care should be given to shop inspection to insure uniformity of thickness.

NOTE.—This will demand, for the four sizes of pumps, pistons as follows:

500-GAL.	750-GAL.
Diameter 14 in.	Diameter 16 in.
Thickness 3½ in.	Thickness 4 in.

1,000-GAL.	1,500-GAL.
Diameter 18 in.	Diameter 20 in.
Thickness 4½ in.	Thickness 5 in.

Manufacturers desiring to use existing patterns approximating these thicknesses may be allowed to do so after due consideration of working drawings.

(Page 132, third paragraph).

27. *Water Cylinders.*

f. Change to read: No stud or tap bolt smaller than ¾-inch should be used to assemble parts subject to the strain of water pressure, as smaller bolts are likely to be twisted off. This does not apply to standard flanges where through bolts are used.

(Page 135, first paragraph).

30. *Water Pistons and Bushings.*

d. Change to read: The length of cylindrical bushing must be such that the outer edge of packing will come short of the edge of bushing at contact stroke about ½ inch and not uncover.

(Page 137, first paragraph).

32. *Size and Number of Pump-Valves.*

a. Change to read: The diameter of the disc of rubber forming the valve must not be greater than 4 inches, nor less than 3 inches.

NOTE.—Three and five-eighths inches diameter appears to be the size best meeting all the conditions, and has been adopted by several manufacturers, but is not insisted upon.

(Page 140, paragraph under table).

33. *Suction Valve Area.*

d. Substitute for the 3½ inch the following for a 3⅝ inch valve:

Diam. Valve.	Diam. of Valve Port Circ.	Circ. of V. P. Circle.	Valve Port Area (Net). Square Inches.
3″	2½″	7.85″	3.5″
3⅝″	3⅛″	9.82″	5.1″
4″	3½″	10.99″	6.3″

Also substitute for the second table in same paragraph the following:

Size of Pump.	500-Gal.			750-Gal.			1,000-Gal.			1,500-Gal.		
Size of Valves......	3″	3⅝″	4″	3″	3⅝″	4″	3″	3⅝″	4″	3″	3⅝″	4″
Necessary number of valves to satisfy (4) under c..	6	5	6	9	8	7	11	9	8	19	14	14
Necessary number of valves to satisfy (3) under c..	7	5	4	10	8	6	13	9	7	21	15	12

In the same article change fine print note to read:

"3⅝″ valve," and not "3½″ valve."

(Page 150, last paragraph).

44. *Discharge Cone.*

b. Change to read: The cone must be provided with an opening to receive the air-vent required by Article 45, etc.

(Page 153, second paragraph).

46. *Priming, Controllable Valve Arrangement.*

d. Change fine print note to read: This valve can preferably be provided with a flange connection in place of the threaded one, and secured to water cylinder with three ⅝″ bolts. This will permit of easier fitting up as to pipe connections. Objection has been raised to this double-seated valve from the possible difficulty of keeping both seats tight. If desired, the stem between the two seats may be somewhat enlarged and provided with a suitable spring, thus giving flexibility between the two seats and preventing all trouble from uneven wear.

STEAM PUMP GOVERNORS AND AUXILIARY PUMPS.

AMENDED RULES AND REQUIREMENTS.

Adopted by the National Fire Protection Association, 1907.

General Rules.

1. Automatically controlled pumps are not acceptable as the sole primary water supply for automatic sprinklers.

Such pumps may occasionally be used to advantage to supplement a weak tank or public water supply until more extensive and permanent improvements can be made.

Experience has shown that the automatic devices for such pumps are easily deranged and require more care than can surely be counted upon at the average risk. As it is absolutely necessary that the primary supply to sprinklers should be instantly and surely available for every moment, night and day, a good gravity supply has been found the best and only thoroughly satisfactory one.

2. Where there is a good gravity supply it is not advisable to equip the fire pump with an automatic governor.

Under these conditions automatic control is not needed, and its first cost and constant use of steam and possible damage to the pump, if the governor goes wrong, had better be avoided. The fire pump should, however, be started as soon as a fire is discovered and operated by hand at good pressure and at such speeds as necessary to give the amount of water needed. Experience shows this to be the simplest, surest, and safest method.

3. Whenever it is necessary to use an automatically controlled pump an auxiliary pump should always be provided to maintain the pressure and supply leakage.

The arrangement of the auxiliary pumps, governors, etc., is shown in Plans A, B and C, following.

The governor on the small pump is set for about 10

pounds higher water pressure than the governor on the main pump, so that the large pump does not start till the pressure has dropped about 10 pounds. The small pump, therefore, does all the work of supplying the leakage in the system and maintaining the pressure.

This saves the large and expensive pump from constant wear and further limits the steam consumption to a pump having a much smaller steam cylinder than the main pump, thus considerably reducing the cost of the steam.

Experience has shown that where the main pump alone is relied upon to keep up the pressure the leakage in the system and past the large plungers allows it to run continuously at a few strokes per minute. After a few years the plungers become so worn that the delivery of the pump is cut down 10 per cent. and often more. This further wastes steam as well as reduces the capacity of the pump for fire fighting.

Valves and other parts of the pump are also likely to get out of order under this service. Moreover, the constant action of the large governor within narrow limits is liable to impair its certainty of action when large delivery is suddenly required.

Governor Construction.

Successful governors vary too greatly in type to admit of uniform mechanical construction. The following specifications cover general points necessary in governors of all types. A searching test under practical working conditions must be the main criterion for acceptance, and for the listing of a governor as an approved device.

The Governor.

1. Must be controlled by the water pressure in the fire system.

2. Must be adjustable to maintain any desired pressure between 75 and 125 pounds using steam at any pressure from 50 to 200 pounds.

3. Must be capable of governing the pump from slow speed to full speed without more than about 5 pounds variation above or below the intended water pressure.

4. Must show no distress under steam pressure at 200 pounds.

5. Must be capable of enduring 240 pounds water pressure without injury.

6. Must have all working parts made of suitable rust-proof material.

7. Must be made so that valve and valve-seat can be removed without disconnecting governor from the piping.

8. Must have maximum working lift of valve afford practically the same steam passage area as that of the steam pipe controlled by the governor.

9. Must have threaded connections for attachment to ordinary pipe fittings.

10. Must have no internal stuffing box or gland.

11. Should preferably have valve and valve seat form an abutment contact when closed.

12. Should preferably admit of full manual movement on inspection, as a proof of working freedom of parts.

13. Should have a tendency to increase rather than decrease the water pressure as the speed of the pump increases.

14. Should respond slowly to any sudden lowering of water pressure, and thus start the pump gradually.

15. Should have concealed mechanism kept at a minimum.

16. Should avoid internal steam joints capable of leaking and passing unregulated steam to the pump.

Auxiliary Pumps.

1. Auxiliary pumps should be of duplex type, brass fitted and with packed pistons or exterior packed plungers.

Brass fitting prevents rusting. Packed pistons make it easy to take care of wear. Exterior packed plungers make it easy to dectect leakage and remedy it.

2. The ratio of steam to water piston areas should be such that the auxiliary pump can maintain the desired water pressure with 50 pounds of steam.

At night boiler pressures may drop to 50 pounds and if this ratio is too small the large pump will start.

A 4½"x2"x4" pump has been used in many situations with good satisfaction. A 4½"x2½"x4" would probably answer equally well in most cases and have the advantage of some greater capacity. Where a larger capacity is needed, as in a very large pipe system, a 5¼"x3"x5" would be advised. These pumps are large enough to have good lifting ability and they are of sufficient capacity to take care of all ordinary leaks and wastes.

In special cases where a larger amount of water must be more or less continuously supplied from a fire system, the auxiliary pump must be larger and may be of any size desired.

The auxiliary pump is of value to keep the main fire pump primed, as well as to maintain the pressure and waste in the fire system.

Installation of Governors and Auxiliary Pumps.

1. Pump governors and auxiliary pumps should be arranged in accordance with one of the three plans, A, B or C, following.

This applies to the scheme of connections and number and location of valves, but not to the exact position of the auxiliary pump and connecting pipes.

2. The main pump and the auxiliary pump must have separate governors made entirely independent by a valve on the water connection of each.

3. The size of governors for the main pump should be as follows:

For 500-gallon pump, 1¼″ governor.
For 750-gallon pump, 1½″ governor.
For 1,000-gallon pump, 1½″ or 2″ governor.
For 1,500-gallon pump, 2″ governor.

The size of the governor is restricted in this way in order that the pump may not run too rapidly for safety in the absence of an attendant, in case of an excessive demand for water, or of a loss of its suction supply. When, in case of fire, the attendant reaches the pump, it is expected that he will control it through the regular throttle valve. However, with the boiler pressures now common, these governors will run the pumps at good speed and often at full speed.

4. The governor for the auxiliary pump should be ¾″ connected into a ½″ steam pipe.

A pipe larger than ½″ is undesirable, as it would permit excessive racing of the small pump if the pressure in the main system were low. A ¾″ governor is required to get the working parts large enough to be reliable.

5. The auxiliary pump should have an independent exhaust.

If the auxiliary pump exhaust is connected into the exhaust of the main pump there is danger of water collecting in the large pump pipe and causing trouble.

6. The water pressure pipe controlling the governors must be of brass. It must connect beyond the main pump discharge check and must have control gates as called for in Art. 2.

Brass is required to avoid trouble from corrosion.

7. Lubricant must be applied so as not to pass through

governors before entering pumps, unless manufacturers specify otherwise.

Unless the governors are designed for it there is danger of the oil gumming up the parts.

8. The governor for large pump to be installed on usual "three valve" by-pass arrangement of steam piping.

This is shown in the cuts, a valve being provided on each side of the governor, while the governor itself is on a by-pass around the main valve. This permits shutting off the governor for repairs and still have steam available on the pump through the main throttle.

9. The auxiliary pump should have a relief valve capable of discharging full capacity of pump without letting pressure rise more than 25 pounds above that at which governor is set.

This is to prevent the small pump putting a dangerous pressure on the system. In some cases the large pump governor is also available for the small pump, but where this is not so a special governor must be provided for it.

10. Duplicate governors, or duplicates of wearing parts, should be kept on hand in all important installations.

This is to avoid delay in repairs.

11. The governor on the auxiliary pump should usually be set at about 10 pounds higher water pressure than the governor of the main pump.

This is to give some margin so that the large pump will not start with small changes in pressure.

12. An auxiliary pump will not operate successfully unless the water end stuffing boxes and joints and suction fittings complete of the main fire pump are in good condition. Further, there should be no serious leaks in any part of the fire system.

Under proper conditions the small pump will move slowly all the time, making just enough strokes to maintain the

small leakage which exists in any considerable equipment. The large pump will remain quiet until there is a demand for water by sprinklers or hose streams.

PLAN A.—For Pumps Taking Water Under a Head. Not Suitable Where Water Must Be Lifted.

In this plan the auxiliary pump is placed on the floor, generally close to the main pump, or may be back against the pump-house wall. All connections should be put in so as to permit easy access to all parts of the large pump. It takes its suction by a short connection to the suction pipe of the large pump, a gate and check valve being provided so that the small suction cannot interfere with the large one. The pump discharges into the discharge pipe of the large pump just beyond the main check valve, a valve being provided so that the small pump can be cut off, while the large one can run as usual.

This plan is not recommended where water must be lifted because the small pump can draw the water up only to the suction deck of the large one. The large pump would then have to develop a vacuum equal to the lift to draw the water into the chambers, which it might not be able to do if the plungers were worn or the pump not fully primed. See Plan B or C for such cases.

G and G1 are the governors. T a steam trap for taking care of condensation. RV is a relief valve to prevent the small pump putting a dangerously high pressure on the system. A valve is provided on each side of the governor on the large pump so that it can be shut off for repairs, etc., and steam still used through the main throttle. The idea is to make it impossible for any derangement of the automatic apparatus to prevent using the large pump in the ordinary way, that is, by hand control through the main throttle.

Sight feed lubricators are shown on both the small and the large pumps. A forced feed lubricator as shown in Plan C could be used if desired.

The check valve on the large pump discharge is shown

in a well in the pump room. The point is to place this check so that should the jar of the pump break the discharge pipe or loosen a joint, or should some other accident happen in or about the pump, this check would be so securely located that it would not be affected, but would close and prevent the waste of water from other sources, as public mains, tanks or other fire pumps connected to the system. The discharge valve on the main pump is bolted directly to the pump outlet, so that no matter what break occurs in the pipe beyond, it can be closed and the pump used through its hose connections.

PLAN B.—For Pumps With Short Suction Pipes and Lifts Not Over Ten Feet, and Not Provided With a Foot Valve. Also Suitable For Use Where Water Is Taken Under a Head.

With this arrangement the small pump is located near the floor and takes its suction from the suction of the large pump at a point just above the level of the suction deck. This small suction pipe should run level, or slightly ascending towards the small pump. The small pump discharges into the pulsation chambers of main pump through the priming connections, and thence through the discharge valves into fire system. A valve is placed on both the suction and discharge of small pump, so that all its connections may be shut off and the large pump operated independently.

This plan will keep the large pump fully primed and will work well on moderate lifts advisably not exceeding 8 to 10 feet. It is not recommended for higher lifts or long suction pipes, as the small pump cannot be relied upon to maintain the suction under severe conditions. See Plan C for such cases.

G and G1 are the governors. T is a steam trap for taking care of condensation.

No relief valve is required, as small pump operates against relief valve of main pump.

A valve is provided on each side of the governor on

the large pump, so that it can be shut off for repairs, etc., and steam still used through the main throttle. The idea is to make it impossible for any derangement of the automatic apparatus to prevent the use of the large pump in the ordinary way, that is, by hand control, through the main throttle.

Sight feed lubricators are shown on both the large and the small pumps. A forced feed lubricator could be used as shown in Plan C, if desired.

The check valve on the main pump discharge is shown in a well outside the pump room, and this is a very good arrangement. The conditions governing the arrangement of this check valve and the main gate on the large pump are fully explained under Plan A. The well for the check valve is desirable, as it not only makes the check valve easily accessible, but also the connection from the small pump discharge is put where it can readily be gotten at.

Plan C.—For Pumps With Long Suction Pipe or Lifts Over Ten Feet, Requiring a Foot Valve, But Suitable For Use With Lesser Lifts or Where Water Is Taken Under a Head.

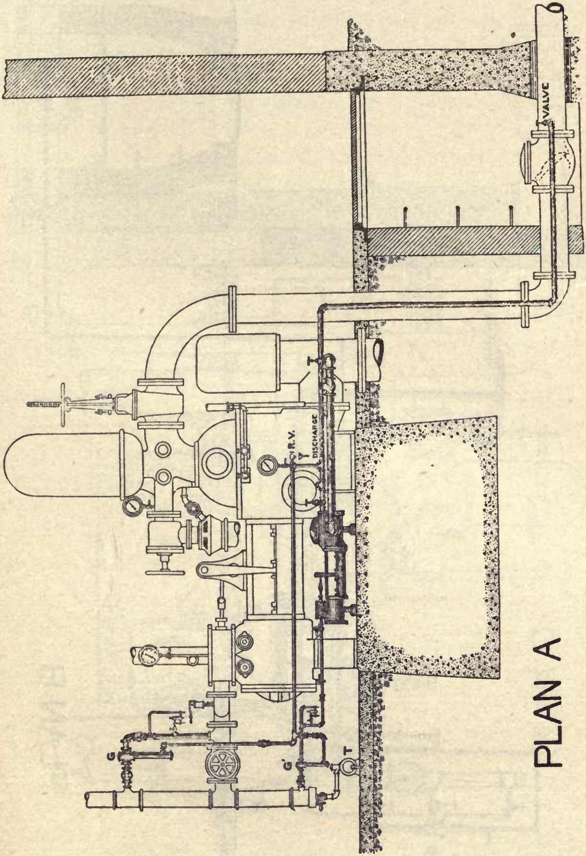
The auxiliary pump is shown on the floor of the pump house, over against the distant side wall. The small pump takes its suction independently of the main one, from some reliable water supply, either that from which the main pump draws or any other sure source. If a near water supply for the small pump can be obtained at a moderate lift it is better than to have it working under a high lift. The auxiliary pump discharges into the suction pipe of the large pump, and on the end of the large pump suction a check or foot valve is placed to retain the water. The foot or check valve used should have metal seat and valve, as, if a soft seat is used, the continual high water pressure on it maintained by the small pump may in time indent the soft material, possibly making the clapper stick, so that the suction action of the large pump would not be sufficient to tear it from its seat. As in the other plans, a valve is

provided on the discharge so that the small pump connections may be shut off and the large pump run independently. The connections from the small to the large pump are shown running up the side wall to a height sufficient to let a man walk under them where they pass overhead to the large pump. The discharge pipe should be carried just below the floor in a trench covered with a plate.

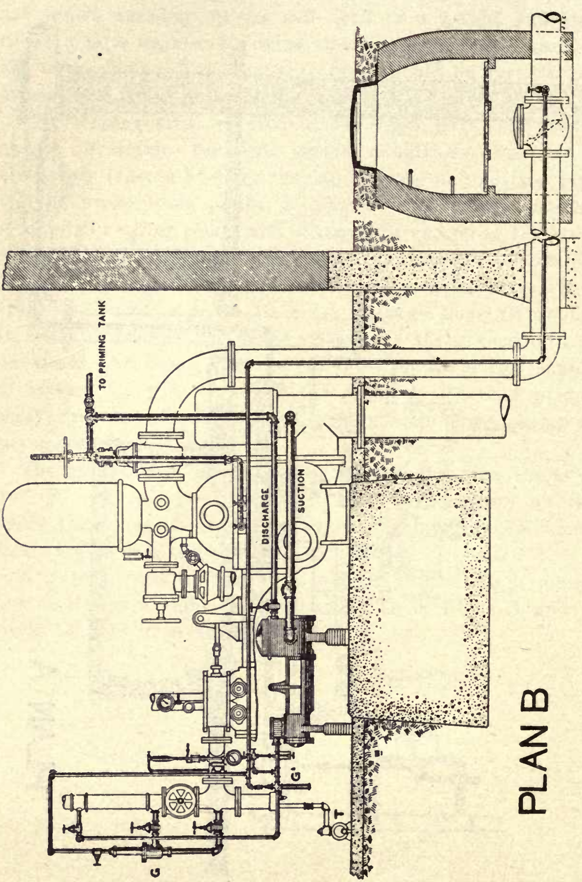
This arrangement is advised for high lifts, but is, of course, available for less severe conditions, because it absolutely insures keeping the large pump and suction pipe full of water, thus giving no chance that when a sudden demand for water comes and steam is turned on to the large pump it will fail to take water and work as desired. Where a pump is equipped with an automatic governor there is almost sure to be some damage done the pump if, when a demand for water arises, and the governor turns on steam, the pump does not at once obtain a full supply of water, for without water the pump would tend to run away, frequently resulting in breaking some part or wrenching some connections loose.

The explanation of details is the same as for Plans A and B. In this case no relief valve is necessary on the small pump, as the relief valve on the large pump would take care of the pressure on both pumps.

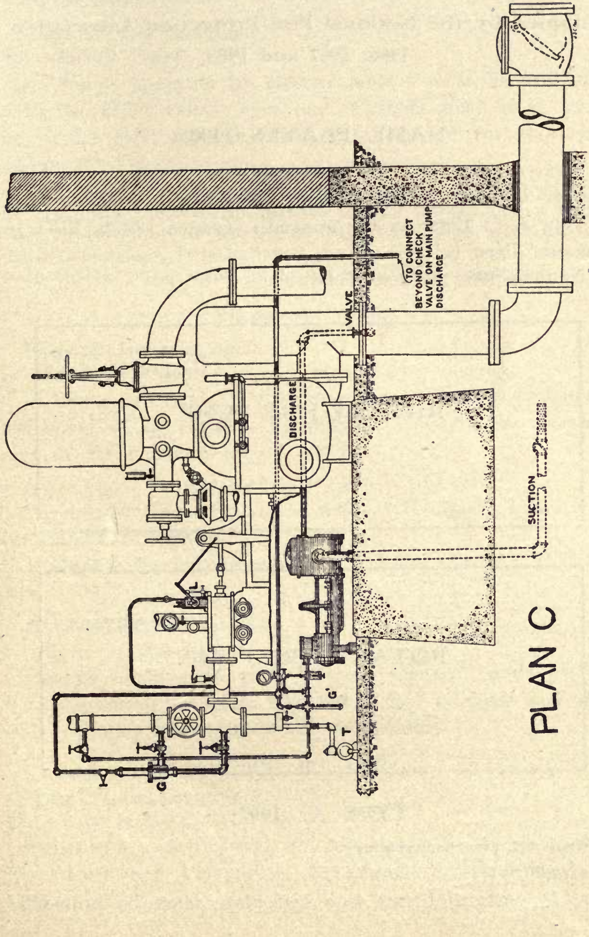
A forced feed lubricator is shown on the large pump, but of course a sight feed lubricator as in Plans A and B could be used if preferred.



PLAN A



PLAN B


TO CONNECT
BEYOND CHECK
VALVE ON MAIN PUMP
DISCHARGE
VALVE
DISCHARGE
SUCTION
L
G'
T
G
PLAN C

SPECIFICATIONS FOR ROTARY FIRE PUMPS.

AMENDMENTS.

Adopted by the National Fire Protection Association, 1906, 1907 and 1908.

NAME PLATES (1906).

(Type A, page 182. Type B, page 201).

Specifications (pages 178 to 194) to be designated as "Type A"; those in the appendix (pages 195 to 215) to remain "Type B."

Name plates to be as follows:

....Pump Company
ROTARY FIRE PUMP.
Type A.
The National Standard.

....Pump Company
ROTARY FIRE PUMP.
Type B.
The National Standard.

TYPE A. (1907)

(Page 184, new paragraph).

9. *Bed Plate.*

a. A substantial cast iron bed plate must be provided,

to which bearings and pump must be firmly secured. Foundation bolts of a size not less than from ⅞″ to 1″, according to size of pump, must be provided for anchoring bed plate to foundations.

(Page 187, new paragraph).

19. *Safety Valve.*

g. Pumps operated by electric motors must be provided with two relief valves, each one of which must be at least of a size next smaller than that required for this size pump.

NOTE.—This is a precaution necessitated by the danger of crippling the electric current by the blowing of a main fuse in case one of the relief valves is inoperative at the desired pressure. It is believed the chances are much less for both valves being stuck or set at too high a pressure.

TYPE A. (1908).

(Page 181, last paragraph).

5. *Capacity Plate.*

a. Change to read: Every pump must bear a conspicuous statement of its capacity securely attached to the inboard side of air chamber, thus:

(Page 182).

Amend wording of plate to read: "Nominal Capacity," instead of "Capacity."

Designate the first paragraph "*b*" and change "5*b*" to read "5*c*."

(Page 183, fifth paragraph).

8. *Body of Pump.*

Change heading to read "Pump Casing" and section "*a*" following to read: The cylindrical portions and the ends of pump casing to be of cast bronze, etc.

TYPE B. (1907).

(Page 204, last paragraph).

12. *Stuffing Boxes.*

Substitute requirements of Associated Factory Mutual Fire Insurance Companies, Specifications of September, 1906.

(Page 208, third paragraph).

15. *Bed Plate.*

e. Change to read: Foundation bolts of a size not less than from 7/8-inch to 1-inch, according to size of pump, must be provided for anchoring bed plate to foundation.

(Page 211, new paragraph).

21. *Safety Valve.*

d. Pumps operated by electric motors must be provided with two relief valves, each one of which must be at least of a size next smaller than that required for this size pump.

NOTE.—This is a precaution necessitated by the danger of crippling the electric circuit by the blowing of a main fuse in case one of the relief valves is inoperative at the desired pressure. It is believed the chances are much less for both valves being stuck or set at too high a pressure.

Type B. (1908).

(Page 199, third paragraph, third line).

3. *Sizes of Pump.*

Change, in third paragraph of fine note, 5.34 to read 5.83.

(Page 201).

Amend wording of plate to read: "Nominal Capacity," instead of "Capacity."

(Page 206, first paragraph, third line).

12. *Stuffing Boxes.*

b. Add: Some means must be provided for preventing the gland nuts from jarring loose.

(Page 206, ninth paragraph, last line).

13. *Gearing.*

c. Add: or the equivalent diametrical pitch.

(Page 209, fourth line.)

16. *Suction and Discharge Openings.*

c. Amend second line of diameters in table to read, for the respective pump sizes, 5-inch or 6-inch, 6-inch or 8-inch, 8-inch or 10-inch.

NOTE.—Starting valve should be connected to the discharge casting at such a point that the water from the

priming pipe will not run out through this starting valve when open.

NOTE.—The object of the change in the table is to permit the manufacturer at his option to make the openings for the hose connection piece the same size as for the main discharge, thus permitting the discharge pipe to lead away from the pump in any one of three different directions. This undoubtedly would be a considerable advantage under many conditions of pump installation.

(Page 211, fifth paragraph).

22. *Discharge Cone.*

b. Amend to read: The cone must be provided with an opening to receive the air-vent pipe required by Steam Pump Rules, Article 45 (page 151).

REMARKS.

Further amendments were proposed to the specifications for Type B Rotary Fire Pumps, as outlined in a committee report printed in the 1908 Proceedings of the National Fire Protection Association (page 167 of the Proceedings).

SPECIFICATIONS FOR ELECTRIC FIRE PUMPS.

AMENDMENTS.

Adopted by the National Fire Protection Association, 1905.

(Page 230, fifth paragraph).

6. *Motor.*

a. Change to read: May be of either the direct or alternating current type and must be designed for voltages within the limits for low potential systems as specified by the "National Electrical Code."

(Page 232, seventh paragraph).

7. *Means of Control, Manual Controller.*

h. Change to read: The starting operation should preferably be accomplished by the use of one handle or lever arm.

NOTE.—When more than one lever or arm must be manipulated, the lever or arm must be interlocked in order to insure their handling in proper order.

(Page 234, first paragraph).

9. *Pump.*

e. Section stricken out.

(Page 234, new articles).

10. *Relief Valve.*

a. Must be provided with two relief valves of the spring "Pop Release" type, attached to discharge casting, and to have hand wheel for pressure regulation. Each valve must have same capacity as required in Steam or Rotary Pump Specifications for pumps of same size. Relief valves to discharge into waste pipes having cone tops with slides so that the discharge from each valve can be made visible.

b. When the supply of water is limited, as from a special suction reservoir or cistern, the waste pipes must drain into such reservoir or cistern, entering as far from the pump

suction as is necessary to prevent the pump from draughting air which may be carried down into the cistern by the discharge from the waste pipes.

NOTE.—In case such reservoir or cistern is above the level of the pump, the waste cones may be omitted.

(Page 234).

11. *Compression Tank for Automatic Pumps.*

Same as old 10, *a*, *b*, *c*.

(Page 235).

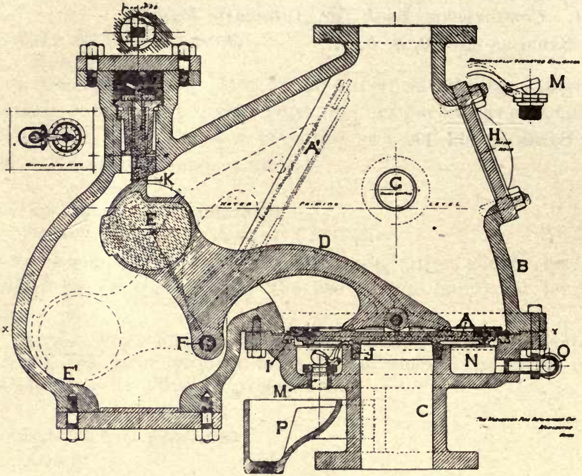
12. *Approval.*

Same as old 11.

"ROCKWOOD" STRAIGHTWAY DRY PIPE VALVE.

(1908.)

(Worcester Fire Extinguisher Company, Worcester, Mass.)



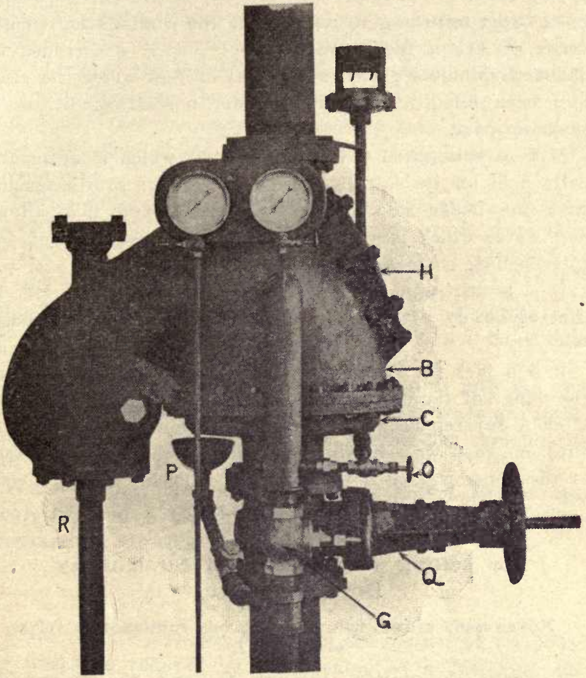
DESCRIPTION.

A is a bronze valve-plate which both closes the water inlet J and seals the air-valve chamber by the contact of the rubber ring at its circumference on a block tin air-valve seat I.

B is the upper part of the valve body, in which the valve-plate A swings when it opens the water inlet.

C is the lower part of the valve body, and carries the air and water seats.

D is a swinging arm, to which are attached the valve-plate A and the counterweight E; the whole swings about the axis F as the valve opens to the position A′ E′ F.



E is an iron ball filled with lead. The weight of the valve-plate A tends to hold itself down on its two seats when shut, and the weight of the ball tends to hold the valve-plate open after it has started to open.

G is the draw-off valve and pipe for emptying the entire system of sprinklers and piping.

H is the hand-hole cover plate, for giving access to all interior parts of the valve.

I and J are the tin air seat ond bronze water seat, respectively.

K is a projection on the ball E adapted to engage a

spring latch L. It is brought into use to prevent the valve-plate from returning to its seats if the combination should occur of (1) a feeble water supply; (2), a corroded or jammed spindle F; (3), a reversal of flow after the riser had been filled with water. Under normal conditions it plays no part.

M is a ball-seated swing check-valve, which is automatically held off its seat by the contact of its arm extension with the under side of the valve-plate, and thus allows any water which may leak by J to run freely out of the intermediate chamber N into the drip cup P.

O is a drip pipe for draining the priming water left in the valve-body after the system has been emptied through G.

R is a jack for raising the lip of the upper body B over the flange of the under body C when it is desired to remove C or A for repairs. To use the jack, hold the pipe post R with one pipe wrench while screwing upwards the coupling at the upper end of R with another wrench.

DIRECTIONS

For setting the Rockwood Straightway Dry-Pipe Valve.

Never apply grease, tallow, or any oily substance to valve seats I or J.

1. Drain the system through G, and the valve-body through O.

2. With a piece of waste, clean the surfaces of (1) the rubber valve; (2) the tin air seat I; (3) the bronze water seat J. With the hand, scoop out any excess of scale or solid particles found in the intermediate chamber N.

3. Push the valve-plate A down towards its seats. It will stop when engaged by the latch L. To lift the latch over the projection on the ball, insert the end of the valve-wrench between the top of the ball and the latch and pry the latter up, thus releasing the valve-plate, which will then seat itself.

4. Pour water (from a hose or pail) into the upper valve body through the hand-hole H until it will almost overflow.

5. Arrange the hand-hole gasket in place and then bolt on the cover-plate. Set the nuts up hard.

6. Pump the necessary air pressure into the system to hold the valve closed against the water pressure in the supply pipe.

NOTE.—With a water pressure of 50 pounds, the air pressure should not be less than 15 pounds nor more than 25 pounds; water pressure of 75 pounds, air pressure of not less than 20 nor more than 30 pounds; water pressure of 100 pounds, air pressure of not less than 25 nor more than 35 pounds; and with a water pressure of 150 pounds, the air pressure should not be less than 35 nor more than 50 pounds.

7. After the air pressure has been pumped into the system, open the main gate valve. If the valve seats are tight, no leakage water will be observed to flow out through the ball check-valve M into the drip cup P.

Water must not be allowed to stand above the Draw-off Valve G, where it might freeze or exert pressure on the Air Valve.

OPERATION

When the air pressure, acting on the surface of the priming water, is relieved by the opening of a sprinkler, the upward pressure of the water underneath the valve plate A causes A to lift, the intermediate chamber N instantly fills, with the result that the entire force of the water, exerted over the full area of the valve plate, pushes it over to the wide-open position and thus leaves a straight unobstructed passage for the water.

INSPECTION

1. Open draw-off valve G to see that the system of sprinklers and piping is free of water down to this level. If any water appears, draw it off and then tightly close valve G.

2. Observe the outlet from the ball-seated swing check-valve M to see that there is no leakage from either valve seat. Insert the middle finger of the hand into this outlet and tip the ball of the check-valve to see that there is entire freedom of movement and no dirt surrounding it.

3. Test automatic alarm occasionally.

TO DRAIN SYSTEM

1. Close main gate valve Q in supply pipe under dry-pipe valve.

2. Open draw-off valve G, closing it (after operation 3) when water has stopped running.

3. Open drip-valves and vents throughout system; then close after water stops running.

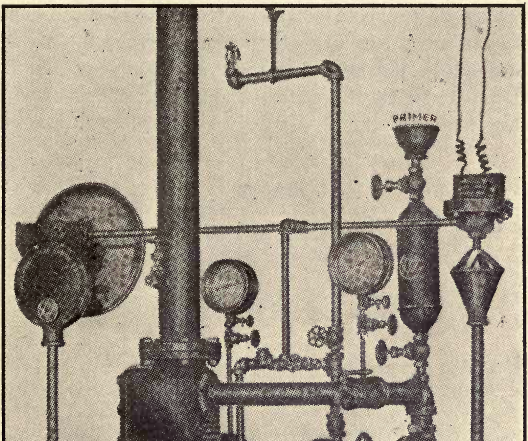
4. Pump a few pounds of air pressure on the system.

5. Open drip-valves and vents to force water from low points of the system.

6. Set DRY-PIPE VALVE and pump up air pressure, as described before under DIRECTIONS.

"INTERNATIONAL" DRY PIPE VALVE.

Model No. 4.



Set "dry," with mechanical and electrical alarms.

(See pages 89 to 93.)

ALARMS ON DRY PIPE SYSTEMS.

On dry pipe systems where air is maintained throughout the year, either the circuit closer or the water motor, or both, may be connected direct to the intermediate chamber of the air-valve. In dry pipe systems where the air is not maintained in the system throughout the year, but water is admitted during the summer, an alarm check valve must be used with the dry pipe valve at the water intake end.

"NIAGARA" DRY PIPE VALVE.

(Niagara Fire Extinguisher Co., Akron, Ohio.)

DESCRIPTION.

Figure 1 shows the "Niagara" dry pipe valve as it appears when set and ready for operation.

Figure 2 is a view similar to Fig. 1, with the doors open to disclose the tripping mechanism.

Figure 3 shows the valve as it appears when tripped, door (17) being removed to clearly disclose parts.

Figure 4 is a diagramatic partial sectional view, designed to show clearly all operating parts. The device is shown "set" in this diagram. The valve consists of the body portion (1) which has bolted thereto the portion (16 A) to which are hinged the doors (17 and 17 A). Secured to the lower portion of (16 A) is the alarm (18).

The water clapper (3) in the lower part of the valve body (1) is held on the seat (2) by means of the toggle, consisting of (4). (5) and (6), the upper toggle strut (5) being mounted upon and bearing against the pin (25). The horizontal thrust of the toggle is resisted by the plunger (7), levers (9) and (10), weight (11), weight hook (33A), trip lever (12A) and air pot disc (15).

The parts (9) and (11) are mounted in (16 A) by "scale bearings." Nearly all of the moving parts of the valve have loose bearings of the ball and socket or "scale bearing" type.

Mounted upon the top of the valve body (1) is a suitable air check valve, consisting of the body portion (37), clapper (36) and seat ring (35). This check valve is provided with a suitable drain (C).

Both the air pot (14) and air check valve (37) are provided with suitable priming devices, consisting of (D) and (23), which permit of priming while system is under air pressure.

INSTRUCTIONS FOR SETTING.

Close gate valve under dry pipe valve and drain the system through (B) and (C). Remove the cover (38) of the air check valve and clean seat (35) and face of air clapper (36). Reseat (36) on (35) and replace cover. Remove the air pot cover (22)

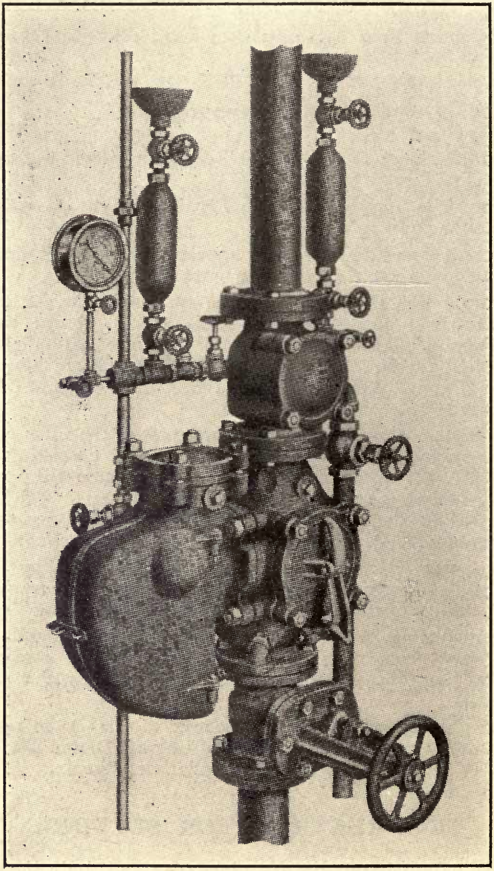


FIG. 1.

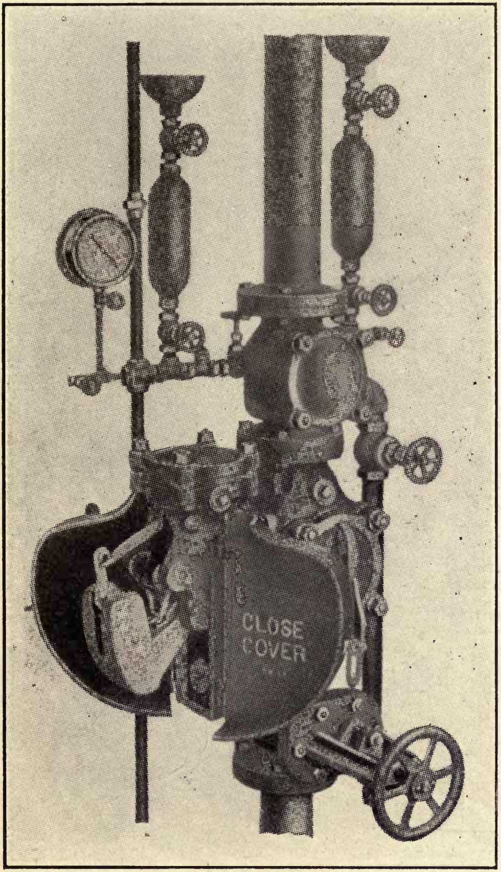


FIG. 2.

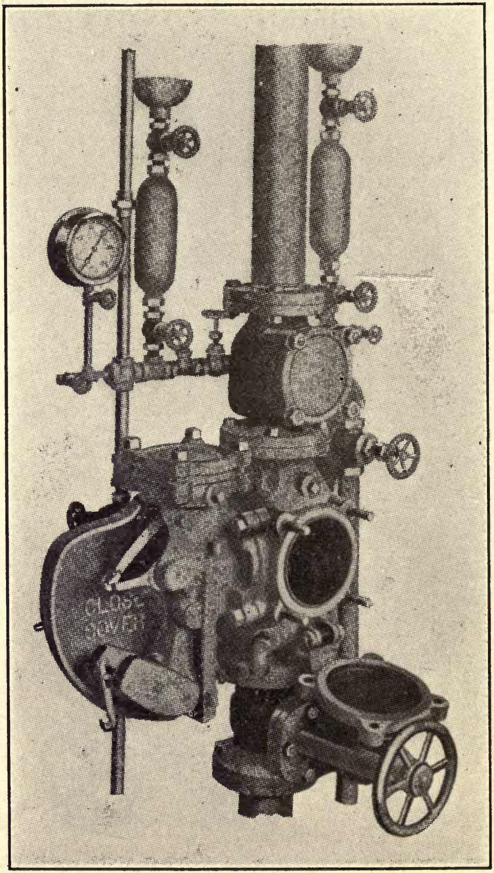


FIG. 3.

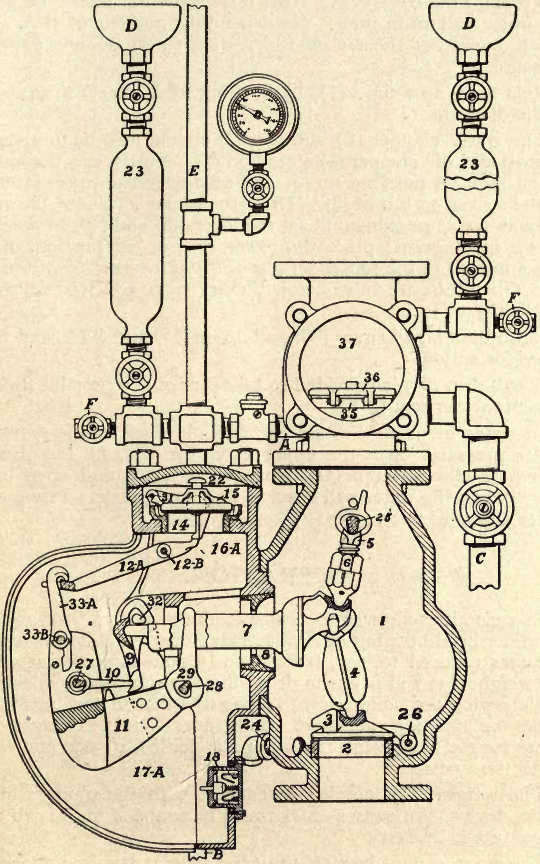

D
D
23
E
23
F
37
36
F
35
A
22
15
31
14
16-A
28
5
12-A
12-B
6
C
33-A
32
33-B
7
1
9
8
27
10
29
28
4
26
11
24
3
2
18
17-A
B

FIG. 4.

and thoroughly clean the air pot (14) and seat of air clapper (15) and replace the cover (22). Next raise the outer end of (12A) so the inner end rests under the depending portion of (15), after which pump up the air on the system to 35 pounds or more pressure.

Next hang up weight (11) by hooking (33A) on (12A) as shown in the diagram.

The water clapper (3) and seat (2) should now be thoroughly cleaned and the clapper (3) seated on (2). Next screw the nut (6) up as high as possible on (5) and set the end of lower strut (4) in the socket on top of (3). Draw the plunger (7) into the valve body as far as possible and set the levers (9) and (10) in position shown in diagram; place the lower end, or ball portion, of the stress nut (6) in the socket on top of (7) and screw down the nut (6). Open the gate valve below the dry valve and see that water seat is tight.

Close the hinged cover (20) and doors (17) and (17A) and valve is set for action.

A ball drip (24) is provided to take care of any possible leakage past the water seat (2–3).

In order to prime the air pot and air check, while system is under pressure, open the upper valve on (23), fill the priming chambers (23) through (D), close upper valve and open lower valve, when the water will descend and cover seats. Prime until water shows at test valves (F).

OPERATION.

In case air is allowed to escape from the system, because of a sprinkler head opening or a valve being opened, and the pressure becomes reduced to, say, from 13 to 15 pounds per square inch, the weight (11) will begin to drop, thereby releasing the lever (9) and allowing the plunger (7) to move to a seat in bushing (8) and close the opening in same. This operation will release the stress toggle and permit the water clapper (3) to open and water to fill the system.

The weight (11), coming in contact with the plunger of the alarm device (18), causes an alarm to be sounded until such time as contact is broken.

The valve cannot be reset until the air seat is raised above the inner portion of (12 A). This guards against any chance of "water column" in air riser pipe, as this cannot be done until all pressure is out of the system.

(Continued from Page 15)

HOSE
International Sprinkler Co.
H. G. Vogel Co.

HOSE RACKS AND REELS
International Sprinkler Co.
H. G. Vogel Co.

HOSE, UNLINED LINEN
International Sprinkler Co.
H. G. Vogel Co.

HYDRANTS
General Fire Extinguisher Co.
International Sprinkler Co.
H. G. Vogel Co.

METERS, WATER
H. G. Vogel Co.

OIL PUMPS, HAND
Deming Co. (Chas. J. Jager Co., 281 Franklin St.)
H. G. Vogel Co.

PIPES
General Fire Extinguisher Co.

PIPE HANGERS
H. G. Vogel Co.

PLAY PIPES
H. G. Vogel Co.

PLAY PIPES, MONITOR NOZZLES
H. G. Vogel Co.

PUMPS, CENTRIFUGAL
H. G. Vogel Co.

PUMPS, ELECTRIC
Deming Co. (Chas. J. Jager Co., 281 Franklin St.)
H. G. Vogel Co.

PUMPS, POWER
Deming Co. (Chas. J. Jager Co., 281 Franklin St.)
H. G. Vogel Co.

PUMPS, ROTARY
Deming Co. (Chas. J. Jager Co., 281 Franklin St.)
H. G. Vogel Co.

PUMPS, STEAM
H. G. Vogel Co.

SPRINKLERS, AUTOMATIC
General Fire Extinguisher Co.
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

STANDPIPES
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

TANKS, GRAVITY
New England Tank & Tower Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

TANK HEATERS
Rockwood Sprinkler Co.
H. G. Vogel Co.

TANKS, PRESSURE
Rockwood Sprinkler Co.
H. G. Vogel Co.

TANK TELL-TALES
New England Tank & Tower Co.
H. G. Vogel Co.

VALVES
International Sprinkler Co.
H. G. Vogel Co.

VALVES, ALARM
General Fire Extinguisher Co.
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

VALVES, CHECK
Deming Co. (Chas. J. Jager Co., 281 Franklin St.)
General Fire Extinguisher Co.
International Sprinkler Co.
H. G. Vogel Co.

VALVES, DRY
General Fire Extinguisher Co.
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

VALVES, FLOAT
Deming Co. (Chas. J. Jager Co., 281 Franklin St.)
H. G. Vogel Co.

VALVES, FOOT
Rockwood Sprinkler Co.
H. G. Vogel Co.

VALVES, INDICATOR GATE
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

VALVES, POST INDICATOR GATE
General Fire Extinguisher Co.
International Sprinkler Co.
Rockwood Sprinkler Co.
H. G. Vogel Co.

BALTIMORE

AIR COMPRESSORS
Deming Co. (Crook-Horner Co.)

OIL PUMPS, HAND
Deming Co. (Crook-Horner Co.)

PUMPS, ELECTRIC
Deming Co. (Crook-Horner Co.)

PUMPS, POWER
Deming Co. (Crook-Horner Co.)

PUMPS, ROTARY
Deming Co. (Crook-Horner Co.)

VALVES, CHECK
Deming Co. (Crook-Horner Co.)

VALVES, FLOAT
Deming Co. (Crook-Horner Co.)

CLEVELAND

AIR COMPRESSORS
International Sprinkler Co.

FIRE ALARM SYSTEMS, AUXILIARY
International Sprinkler Co.

FITTINGS
General Fire Extinguisher Co.

HOSE
International Sprinkler Co.

HOSE RACKS AND REELS
International Sprinkler Co.

HOSE, UNLINED LINEN
International Sprinkler Co.

HYDRANTS
General Fire Extinguisher Co.
International Sprinkler Co.

PIPES
General Fire Extinguisher Co.

SPRINKLERS, AUTOMATIC
General Fire Extinguisher Co.
International Sprinkler Co.

STANDPIPES
International Sprinkler Co.

VALVES
International Sprinkler Co.

VALVES ALARM
General Fire Extinguisher Co.
International Sprinkler Co.

VALVES, CHECK
General Fire Extinguisher Co.
International Sprinkler Co.

VALVES, DRY
General Fire Extinguisher Co.
International Sprinkler Co.

VALVES, INDICATOR GATE
International Sprinkler Co.

VALVES, POST INDICATOR GATE
General Fire Extinguisher Co.
International Sprinkler Co.

BUFFALO

AIR COMPRESSORS
Deming Co. (Root, Neal & Co., 178 Main St.)
H. G. Vogel Co.

ELECTRICAL APPARATUS
H. G. Vogel Co.

FIRE DEPARTMENT SUPPLIES
H. G. Vogel Co.

FIRE PAILS
H. G. Vogel Co.

FITTINGS
General Fire Extinguisher Co.

GAGES, PRESSURE
H. G. Vogel Co.

GAGES, WATER
H. G. Vogel Co.

GOVERNORS FOR PUMPS
H. G. Vogel Co.

HOSE
H. G. Vogel Co.

HOSE RACKS AND REELS
H. G. Vogel Co.

HOSE, UNLINED LINEN
H. G. Vogel Co.

HYDRANTS
General Fire Extinguisher Co.
H. G. Vogel Co.

METERS, WATER
H. G. Vogel Co.

OIL PUMPS, HAND
Deming Co. (Root, Neal & Co., 178 Main St.)
H. G. Vogel Co.

PIPES
General Fire Extinguisher Co.

PIPE HANGERS
H. G. Vogel Co.

PLAY PIPES
H. G. Vogel Co.

PLAY PIPES, MONITOR NOZZLES
H. G. Vogel Co.

PUMPS, CENTRIFUGAL
H. G. Vogel Co.

PUMPS, ELECTRIC
Deming Co. (Root, Neal & Co., 178 Main St.)
H. G. Vogel Co.

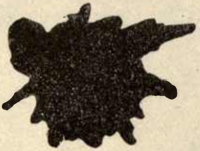
PUMPS, POWER
Deming Co. (Root, Neal & Co., 178 Main St.)
H. G. Vogel Co.

PUMPS, ROTARY
Deming Co. (Root, Neal & Co., 178 Main St.)
H. G. Vogel Co.

PUMPS, STEAM
H. G. Vogel Co.

SPRINKLERS, AUTOMATIC
General Fire Extinguisher Co.
H. G. Vogel Co.

STANDPIPES
H. G. Vogel Co.



A costly fire is a blot on the manager's reputation

There's no excuse for the management which suffers a serious loss through fire because positive means of fire prevention are easily obtained.

When

INTERNATIONAL SPRINKLERS

are installed, fire cannot gain sufficient headway to cause appreciable damage They are infallable and are not costly to install or maintain

Insurance interests endorse them, your interests demand them. Details in our booklet. Want a copy?

INTERNATIONAL SPRINKLER CO.
TRADE MARK REGISTERED

International Sprinkler Co.
Philadelphia

TANKS, GRAVITY
H. G. Vogel Co.

TANK HEATERS
H. G. Vogel Co.

TANKS, PRESSURE
H. G. Vogel Co.

TANK TELL-TALES
H. G. Vogel Co.

VALVES
H. G. Vogel Co.

VALVES, ALARM
General Fire Extinguisher Co.
H. G. Vogel Co.

VALVES, CHECK
Deming Co. (Root, Neal & Co., 178 Main St.)
General Fire Extinguisher Co.
H. G. Vogel Co.

VALVES, DRY
General Fire Extinguisher Co.
H. G. Vogel Co.

VALVES, FLOAT
Deming Co. (Root, Neal & Co., 178 Main St.)
H. G. Vogel Co.

VALVES, FOOT
H. G. Vogel Co.

VALVES, INDICATOR GATE
H. G. Vogel Co.

VALVES, POST INDICATOR GATE
General Fire Extinguisher Co.
H. G. Vogel Co.

PITTSBURG

AIR COMPRESSORS
Deming Co. (Harris Pump & Supply Co., 320 Second Ave.)
International Sprinkler Co.

FIRE ALARM SYSTEMS, AUXILIARY
International Sprinkler Co.

HOSE
International Sprinkler Co.

HOSE RACKS AND REELS
International Sprinkler Co.

HOSE, UNLINED LINEN
International Sprinkler Co.

HYDRANTS
International Sprinkler Co.

OIL PUMPS, HAND
Deming Co. (Harris Pump & Supply Co., 320 Second Ave.)

PUMPS, ELECTRIC
Deming Co. (Harris Pump & Supply Co., 320 Second Ave.)

PUMPS, POWER
Deming Co. (Harris Pump & Supply Co., 320 Second Ave.)

PUMPS, ROTARY
Deming Co. (Harris Pump & Supply Co., 320 Second Ave.)

SPRINKLERS, AUTOMATIC
International Sprinkler Co.

STANDPIPES
International Sprinkler Co.

VALVES
International Sprinkler Co.

VALVES, ALARM
International Sprinkler Co.

VALVES, CHECK
Deming Co. (Harris Pump & Supply Co., 320 Second Ave.)
International Sprinkler Co.

VALVES, DRY
International Sprinkler Co.

VALVES, FLOAT
Deming Co. (Harris Pump & Supply Co., 320 Second Ave.)

VALVES, INDICATOR GATE
International Sprinkler Co.

VALVES, POST INDICATOR GATE
International Sprinkler Co.

SAN FRANCISCO

AIR COMPRESSORS
Deming Co. (Henshaw, Bulkley & Co.)
International Sprinkler Co.

FIRE ALARM SYSTEMS, AUXILIARY
International Sprinkler Co.

HOSE
International Sprinkler Co.

HOSE RACKS AND REELS
International Sprinkler Co.

HOSE, UNLINED LINEN
International Sprinkler Co.

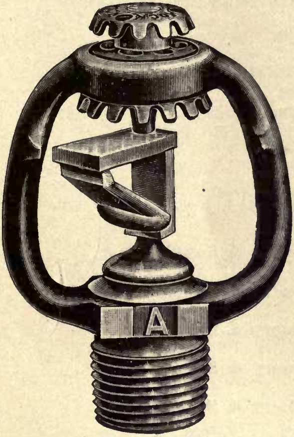
HYDRANTS
International Sprinkler Co.

OIL PUMPS, HAND
Deming Co. (Henshaw, Bulkley & Co.)

PUMPS, ELECTRIC
Deming Co. (Henshaw, Bulkley & Co.)

ROCKWOOD
AUTOMATIC SPRINKLERS
AND
DRY-PIPE VALVES
(STRAIGHT WAY)

APPROVED BY ALL INSURANCE INTERESTS



MANUFACTURERS

ENGINEERS and

CONTRACTORS

FOR

COMPLETE

SPRINKLER

EQUIPMENTS

THE ROCKWOOD SPRINKLER

ROCKWOOD SPRINKLER CO.

Offices at which Rockwood Sprinkler Apparatus is sold :

For NEW ENGLAND AND CANADA . .	2 Arch St., Worcester, Mass. 141 Milk St., Boston, Mass.
For NEW YORK, NEW JERSEY, PENN'A .	2 Rector St., New York, N.Y.
For CENTRAL AND SOUTHERN STATES .	206 LaSalle St., Chicago, Ill.
For PACIFIC COAST STATES . . .	Seattle, Washington
For TEXAS	1210½ Congress Ave., Houston, Texas

PUMPS, POWER
Deming Co. (Henshaw, Bulkley & Co.)
PUMPS, ROTARY
Deming Co. (Henshaw, Bulkley & Co.)
SPRINKLERS, AUTOMATIC
International Sprinkler Co.
STANDPIPES
International Sprinkler Co.
VALVES
International Sprinkler Co.
VALVES, ALARM
International Sprinkler Co.
VALVES, CHECK
Deming Co. (Henshaw, Bulkley & Co.)
International Sprinkler Co.
VALVES, DRY
International Sprinkler Co.
VALVES, FLOAT
Deming Co. (Henshaw, Bulkley & Co.)
VALVES, INDICATOR GATE
International Sprinkler Co.
VALVES, POST INDICATOR GATE
International Sprinkler Co.

DETROIT

AIR COMPRESSORS
Deming Co. (Kerr Machinery & Supply Co.)
OIL PUMPS, HAND
Deming Co. (Kerr Machinery & Supply Co.)
PUMPS, ELECTRIC
Deming Co. (Kerr Machinery & Supply Co.)
PUMPS, POWER
Deming Co. (Kerr Machinery & Supply Co.)
PUMPS, ROTARY
Deming Co. (Kerr Machinery & Supply Co.)
VALVES, CHECK
Deming Co. (Kerr Machinery & Supply Co.)
VALVES, FLOAT
Deming Co. (Kerr Machinery & Supply Co.)

CINCINNATI

AIR COMPRESSORS
Deming Co. (Fairbanks, Morse & Co.)
International Sprinkler Co.
Niagara Fire Extinguisher Co.
H. G. Vogel Co.
ELECTRICAL APPARATUS
H. G. Vogel Co.
FIRE ALARM SYSTEMS, AUXILIARY
International Sprinkler Co.

FIRE DEPARTMENT SUPPLIES
H. G. Vogel Co.
FIRE PAILS
H. G. Vogel Co.
GAGES, PRESSURE
H. G. Vogel Co.
GAGES, WATER
H. G. Vogel Co.
GOVERNORS FOR PUMPS
H. G. Vogel Co.
HOSE
International Sprinkler Co.
H. G. Vogel Co.
HOSE RACKS AND REELS
International Sprinkler Co.
H. G. Vogel Co.
HOSE, UNLINED LINEN
International Sprinkler Co.
H. G. Vogel Co.
HYDRANTS
International Sprinkler Co.
H. G. Vogel Co.
METERS, WATER
H. G. Vogel Co.
OIL PUMPS, HAND
Deming Co. (Fairbanks, Morse & Co.)
H. G. Vogel Co.
PIPE HANGERS
Niagara Fire Extinguisher Co.
H. G. Vogel Co.
PLAY PIPES
H. G. Vogel Co.
PLAY PIPES, MONITOR NOZZLES
H. G. Vogel Co.
PUMPS, CENTRIFUGAL
H. G. Vogel Co.
PUMPS, ELECTRIC
Deming Co. (Fairbanks, Morse & Co.)
H. G. Vogel Co.
PUMPS, POWER
Deming Co. (Fairbanks, Morse & Co.)
H. G. Vogel Co.
PUMPS, ROTARY
Deming Co. (Fairbanks, Morse & Co.)
H. G. Vogel Co.
PUMPS, STEAM
H. G. Vogel Co.
SPRINKLERS, AUTOMATIC
International Sprinkler Co.
Niagara Fire Extinguisher Co.
H. G. Vogel Co.
STANDPIPES
International Sprinkler Co.
H. G. Vogel Co.

TANKS, GRAVITY
H. G. Vogel Co.

TANK HEATERS
Niagara Fire Extinguisher Co.
H. G. Vogel Co.

TANKS, PRESSURE
H. G. Vogel Co.

TANK TELL-TALES
H. G. Vogel Co.

VALVES
International Sprinkler Co.
Niagara Fire Extinguisher Co.
H. G. Vogel Co.

VALVES, ALARM
International Sprinkler Co.
Niagara Fire Extinguisher Co.
H. G. Vogel Co.

VALVES, CHECK
Deming Co. (Fairbanks, Morse & Co.)
International Sprinkler Co.
Niagara Fire Extinguisher Co.
H. G. Vogel Co.

VALVES, DRY
International Sprinkler Co.
Niagara Fire Extinguisher Co.
H. G. Vogel Co.

VALVES, FLOAT
Deming Co. (Fairbanks, Morse & Co.)
H. G. Vogel Co.

VALVES, FOOT
H. G. Vogel Co.

VALVES, INDICATOR GATE
International Sprinkler Co.
H. G. Vogel Co.

VALVES, POST INDICATOR GATE
International Sprinkler Co.
H. G. Vogel Co.

NEW ORLEANS

AIR COMPRESSORS
Deming Co. (Wilmot Machinery Co.)
International Sprinkler Co.

FIRE ALARM SYSTEMS, AUXILIARY
International Sprinkler Co.

FITTINGS
General Fire Extinguisher Co.

HOSE
International Sprinkler Co.

HOSE RACKS AND REELS
International Sprinkler Co.

HOSE, UNLINED LINEN
International Sprinkler Co.

HYDRANTS
General Fire Extinguisher Co.
International Sprinkler Co.

OIL PUMPS, HAND
Deming Co. (Wilmot Machinery Co.)
PIPES
General Fire Extinguisher Co.
PUMPS, ELECTRIC
Deming Co. (Wilmot Machinery Co.)
PUMPS, POWER
Deming Co. (Wilmot Machinery Co.)
PUMPS, ROTARY
Deming Co. (Wilmot Machinery Co.)
SPRINKLERS, AUTOMATIC
General Fire Extinguisher Co.
International Sprinkler Co.
STANDPIPES
International Sprinkler Co.
VALVES
International Sprinkler Co.
VALVES, ALARM
General Fire Extinguisher Co.
International Sprinkler Co.
VALVES, CHECK
Deming Co. (Wilmot Machinery Co.)
General Fire Extinguisher Co.
International Sprinkler Co.
VALVES, DRY
General Fire Extinguisher Co.
International Sprinkler Co.
VALVES, FLOAT
Deming Co. (Wilmot Machinery Co.)
VALVES, INDICATOR GATE
International Sprinkler Co.
VALVES, POST INDICATOR GATE
General Fire Extinguisher Co.
International Sprinkler Co.

WASHINGTON

AIR COMPRESSORS
Deming Co. (Columbia Pump & Well Co.)
OIL PUMPS, HAND
Deming Co. (Columbia Pump & Well Co.)
PUMPS, ELECTRIC
Deming Co. (Columbia Pump & Well Co.)
PUMPS, POWER
Deming Co. (Columbia Pump & Well Co.)
PUMPS, ROTARY
Deming Co. (Columbia Pump & Well Co.)
VALVES, CHECK
Deming Co. (Columbia Pump & Well Co.)
VALVES, FLOAT
Deming Co. (Columbia Pump & Well Co.)

MINNEAPOLIS

AIR COMPRESSORS
International Sprinkler Co.

FIRE ALARM SYSTEMS, AUXILIARY
International Sprinkler Co.

GAS ENGINE POWER
Challenge Co.

HOSE
International Sprinkler Co.

HOSE RACKS AND REELS
International Sprinkler Co.

HOSE, UNLINED LINEN
International Sprinkler Co.

HYDRANTS
International Sprinkler Co.

SPRINKLERS, AUTOMATIC
International Sprinkler Co.

STANDPIPES
International Sprinkler Co.

TANKS, GRAVITY
Challenge Co.

TANK TELL-TALES
Challenge Co.

TANK TOWERS, STEEL
Challenge Co.

VALVES
Challenge Co.
International Sprinkler Co.

VALVES, ALARM
International Sprinkler Co.

VALVES, CHECK
International Sprinkler Co.

VALVES, DRY
International Sprinkler Co.

VALVES, FLOAT
Challenge Co.

VALVES, INDICATOR GATE
International Sprinkler Co.

VALVES, POST INDICATOR GATE
International Sprinkler Co.

LOUISVILLE

AIR COMPRESSORS
Deming Co. (Laib Co.)

OIL PUMPS, HAND
Deming Co. (Laib Co.)

PUMPS, ELECTRIC
Deming Co. (Laib Co.)

PUMPS, POWER
Deming Co. (Laib Co.)

PUMPS, ROTARY
Deming Co. (Laib Co.)

VALVES, CHECK
Deming Co. (Laib Co.)

VALVES, FLOAT
Deming Co. (Laib Co.)

KANSAS CITY

AIR COMPRESSORS
Deming Co. (English Iron Works Co.)
International Sprinkler Co.

FIRE ALARM SYSTEMS, AUXILIARY
International Sprinkler Co.

GAS ENGINE POWER
Challenge Co.

HOSE
International Sprinkler Co.

HOSE RACKS AND REELS
International Sprinkler Co.

HOSE, UNLINED LINEN
International Sprinkler Co.

HYDRANTS
International Sprinkler Co.

OIL PUMPS,HAND
Deming Co. (English Iron Works Co.)

PUMPS, ELECTRIC
Deming Co. (English Iron Works Co.)

PUMPS, POWER
Deming Co. (English Iron Works Co.)

PUMPS, ROTARY
Deming Co. (English Iron Works Co.)

SPRINKLERS, AUTOMATIC
International Sprinkler Co.

STANDPIPES
International Sprinkler Co.

TANKS, GRAVITY
Challenge Co.

TANK TELL-TALES
Challenge Co.

TANK TOWERS, STEEL
Challenge Co.

VALVES
Challenge Co.
International Sprinkler Co.

VALVES, ALARM
International Sprinkler Co.

VALVES, CHECK
Deming Co. (English Iron Works Co.)
International Sprinkler Co.

VALVES, DRY
International Sprinkler Co.
VALVES, FLOAT
Challenge Co.
Deming Co. (English Iron Works Co.)
VALVES, INDICATOR GATE
International Sprinkler Co.
VALVES, POST INDICATOR GATE
International Sprinkler Co.

DENVER

AIR COMPRESSORS
Deming Co. (Hendrie & Bolthoff Mfg. & Supply Co.)
International Sprinkler Co.
FIRE ALARM SYSTEMS, AUXILIARY
International Sprinkler Co.
HOSE
International Sprinkler Co.
HOSE RACKS AND REELS
International Sprinkler Co.
HOSE, UNLINED LINEN
International Sprinkler Co.
HYDRANTS
International Sprinkler Co.
OIL PUMPS, HAND
Deming Co. (Hendrie & Bolthoff Mfg. & Supply Co.)
PUMPS, ELECTRIC
Deming Co. (Hendrie & Bolthoff Mfg. & Supply Co.)
PUMPS, POWER
Deming Co. (Hendrie & Bolthoff Mfg. & Supply Co.)
PUMPS, ROTARY
Deming Co. (Hendrie & Bolthoff Mfg. & Supply Co.)
SPRINKLERS, AUTOMATIC
International Sprinkler Co.
STANDPIPES
International Sprinkler Co.
VALVES
International Sprinkler Co.
VALVES, ALARM
International Sprinkler Co.
VALVES, CHECK
Deming Co. (Hendrie & Bolthoff Mfg. & Supply Co.)
International Sprinkler Co.
VALVES, DRY
International Sprinkler Co.
VALVES, FLOAT
Deming Co. (Hendrie & Bolthoff Mfg. & Supply Co.)
VALVES, INDICATOR GATE
International Sprinkler Co.
VALVES, POST INDICATOR GATE
International Sprinkler Co.

ATLANTA

AIR COMPRESSORS
Deming Co. (Dunn Machinery Co.)
International Sprinkler Co.

FIRE ALARM SYSTEMS, AUXILIARY
International Sprinkler Co.

FITTINGS
General Fire Extinguisher Co.

HOSE
International Sprinkler Co.

HOSE RACKS AND REELS
International Sprinkler Co.

HOSE, UNLINED LINEN
International Sprinkler Co.

HYDRANTS
General Fire Extinguisher Co.
International Sprinkler Co.

OIL PUMPS, HAND
Deming Co. (Dunn Machinery Co.)

PIPES
General Fire Extinguisher Co.

PUMPS, ELECTRIC
Deming Co. (Dunn Machinery Co.)

PUMPS, POWER
Deming Co. (Dunn Machinery Co.)

PUMPS, ROTARY
Deming Co. (Dunn Machinery Co.)

SPRINKLERS, AUTOMATIC
General Fire Extinguisher Co.
International Sprinkler Co.

STANDPIPES
International Sprinkler Co.

VALVES
International Sprinkler Co.

VALVES, ALARM
General Fire Extinguisher Co.
International Sprinkler Co.

VALVES, CHECK
Deming Co. (Dunn Machinery Co.)
General Fire Extinguisher Co.
International Sprinkler Co.

VALVES, DRY
General Fire Extinguisher Co.
International Sprinkler Co.

VALVES, FLOAT
Deming Co. (Dunn Machinery Co.)

VALVES, INDICATOR GATE
International Sprinkler Co.

VALVES, POST INDICATOR GATE
General Fire Extinguisher Co.
International Sprinkler Co.

per l'
uso nel